CANADA

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Science and Technology for Development

A Review of Schools of Thought on Science, Technology, Development, and Technical Change

STPI Module 1

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for Development

STPI MODULE 1: A REVIEW OF SCHOOLS OF THOUGHT ON SCIENCE, TECHNOLOGY, DEVELOPMENT, AND TECHNICAL CHANGE

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FOREWORD

This module constitutes an integral part of the Main Comparative Report of the Science and Technology Policy Instruments (STPI) project, a large research effort that examines the design and implementation of science and technology policies in 10 developing countries (Appendixes 1 and 2).

The STPI project generated a large number of reports, essays, and monographs covering a great variety of themes in science and technology for development. More than 250 documents were produced by the country teams and the Field Coordinator's Office, and this proliferation posed rather difficult problems during the comparative phase of the project. It was decided that a Main Comparative Report, covering the substantive aspects of the research work of the country teams would be published, and that several monographs treating specific subjects would complement it.

The Main Comparative Report is organized in three parts. The first consists of a short essay covering the main policy and research issues identified through the research, and the second contains the most relevant results of a comparative nature that were obtained in the project. These first two parts have been published by the International Development Research Centre in a single volume in English, Spanish, and French (109e, 109s, and 109f).

The third part of the Main Comparative Report consists of 12 modules containing material selected from the many reports produced during the STPI project. They provide the supporting material for the findings described and the assertions made in the first two parts of the Main Comparative Report.

The modules were prepared by several consultants, and given the diversity of topics covered, the IDRC staff did not consider it desirable nor possible to impose a single format or structure for their preparation. The reader will find a diversity of styles and structures in the modules and will find that the selection of texts reflects the views of the consultant who compiled the module. However, the modules were prepared in close collaboration with the Field Coordinator and were also submitted to a STPI editorial committee who ensured that they provided a representative sample of STPI material. They should be read in conjunction with the first two parts of the Main Comparative Report.

Francisco R. Sagasti

INTRODUCTION

The purpose of this module is to examine different approaches to the study of the interrelations between science, technology, development, industrialization, and technical change to provide a theoretical background to the efforts of the STPI project. During both the organization of the project and the conduct of the research, the approaches and points of view of different authors were extensively discussed by the members of the STPI network. From the study of these schools of thought and from dissatisfaction with the current state of knowledge, it became clear that additional empirical research was needed to postulate more adequate theories of development that would include explicitly scientific and technological considerations.

The STPI project did not postulate a particular theory from which to derive hypotheses on the emergence and effectiveness of policy instruments for science and technology. Therefore, this review complements the findings summarized in other modules in this series and in the other reports prepared as a result of the STPI project. The schools of thought, points of view, and theories examined below were discussed continually by the members of the STPI network throughout the project, although the decision to prepare a review essay was only taken toward the end of the project, at the New Delhi meeting of the Coordinating Committee in January 1976.

The interaction between socioeconomic processes and science and technology is discussed next, followed by sections on the different approaches to the study of technology, industrialization, and development. These include neoclassical theory and its ramifications regarding production, trade, innovation, and the problem of factor proportions; the historical perspective of Rostow's stages of growth theory; the structuralist view of the U.N. Economic Commission for Latin America (ECLA); the dependency school of thought; the developments in oligopoly theory; and the Marxist theories of capital accumulation at the international level.

A discussion of the nature of technical change at the enterprise level follows the review of the different development theories and their technological implications. The literature on this subject is varied and extensive, although it refers primarily to technical change in enterprises of advanced industrialized countries. The discussion is complemented by observations about the nature of technical change in developing countries. The module closes with some remarks on the policy implications of the different schools of thought and mentions some studies in the area of policy implementation.

Before entering into the subject matter, a few comments on the interplay between socioeconomic forces and technical progress are in order. The structure and logic of the system of production provide the context for the evolution of technology and, in consequence, technological progress cannot be examined independently of the social forces that led to it and allowed its materialization and subsequent incorporation into productive and social activities. This view can be adopted as a way of describing historically observed processes (1), but it can also be taken in a normative sense, with a new style of development and a new logic of production leading to a new style and logic of technological progress (2).

However, there is also a strong feedback from the processes of scientific and technical development to the evolution of socioeconomic forces, which takes the form of removing constraints and creating new opportunities. The progress of science and technology is continually altering the characteristics of the productive system, both in capitalist and socialist economies (3), and it is impossible to ignore the fact that the emergence of organized industrial research and the rise of science-related technology (4) have been decisive in opening new avenues for capital accumulation and in fueling the process of industrial growth. Nevertheless, this does not imply accepting the "technological imperative which states that what is technically feasible will actually be done (for better or worse), for there is evidence that technical developments, at least in Western market economies, are usually subordinated to the interests of those who control the generation of knowledge and its application to production (enterprises and entrepreneurs), such that in some cases new technologies may be supressed to avoid potential disruption of the existing order (5).

Summarizing: the logic of production and the evolution of productive forces set the stage for the emergence of technical developments and determine the use that will be made of them. In turn, technological progress removes constraints and provides the productive system with opportunities to expand. While accepting a strong two-way interaction in the interplay between the development of productive forces and of science and technology, the main role seems to be with the former.

An important distinction that should be kept in mind is that made between the "use value" and the "exchange value" of technology. This requires that technology be conceptualized as a commodity or merchandise, which is adequate from the perspective of production, trade, and utilization of industrial technology taken in this report (it is, however, insufficient when broader social, educational, and cultural aspects of the impact of technology are examined). This distinction has been drawn recently by Gonod (6) and by Sercovich (7), who point out that from the point of view of use value, technology can be considered as the compound of applied knowledge instrumental to the production, management, marketing, and distribution of goods and services. Technology as a use value emphasizes the intrinsic characteristics of a particular body of knowledge and the ways in which it can be employed. Most of the theoretical literature on the interrelations between technology and development treats technology from this perspective.

From an exchange value point of view, technology can be considered as a privately appropriated asset conveying market power. As such it has the potential capacity to earn monopoly rents for those who control and exploit it. This introduces the perspective of power relations and the way in which technology is appropriated as a means of extracting surplus from those who need to aquire it through trade. The use value of technology is not manifested through the exchange process and the price associated with the transaction.

In the first conception, within certain limits, technology can be considered largely universal in the sense that its usefulness transcends particular forms of social organization (8). However, in the second conception, it is peculiar - but not exclusive - to the capitalist economy and aquires its most conspicuous form of development as a commodity in the oligopolistic stage of market organization. Proprietary knowledge, irrespective of how useful it may be for various people in different places, has a market price. Therefore, the access to a technique, and hence its use value to those who need it, is conditioned by its exchange value and the associated market price, which in turn is determined by the relative bargaining power of the buyer and the seller (9). Finally, the relative bargaining power (and hence the market price associated with the exchange value of a technology) will be determined by the structure of productive forces and the overall form of social organization.

NEOCLASSICAL THEORY

The neoclassical school is the product of more than one hundred years of work by economists and has been able to establish a highly coherent and formally rigorous theoretical framework to which its followers attribute an almost universal validity. Stemming from the utilitarian thinking of the 19th century, the analysis is centred on the static model of "pure and perfect" competition and on the internal equilibrium and coherence of the spheres of production and consumption as the desideratum of the analytical proposals.

To see how neoclassical theory has led to various ways of dealing with technical progress, reference will be made to production functions, international trade, Schumpeter's theory of innovations, and the problem of factor proportions.

Production and Technical Progress Functions (10)

The changes in production levels brought about by technical progress incorporated into productive activities through machinery and human resources are analyzed using the concept of the "production function." A production function expresses the relation between the maximum amount of output and the inputs (primarily capital and labour) required to produce it; by doing so it describes the manner in which inputs combine with each other in varying proportions to produce any given output. The production function enters economic analysis as a datum given by technological or extraeconomic considerations, and the technology embedded in the production relation acts as a constraint on decision making.

The production function embodies an abstract technology. Its generality derives from the fact that it abstracts from certain technical and economic magnitudes and in doing so enables a variety of economic problems to be analyzed and different types of technological change to be described. An abstract technology is characterized by its efficiency, which determines the output that results from given inputs; by the technologically determined economies of scale, which describe the extent to which a proportionate change in inputs generates a proportionate change in output; by the capital intensity, which denotes the specific weight placed on capital as compared with labour inputs; and by the ease with which capital is substituted for labour, that is, the elasticity of substitution (11).

Production functions have been used by economists in the neoclassical tradition to describe behaviour at the productive unit level and, using aggregate production functions, at the sectoral and national levels. However, the construction of aggregate production functions is fraught with difficulties that require the introduction of many simplifying assumptions. These diminish considerably their possible usefulness for the analysis of real economic phenomena. Furthermore, the problems of defining and measuring the capital and labour inputs to relate them to output have given rise to a variety of theoretical and practical discussions and controversies (12).

It was only in the late 1950's and the 1960's that economists turned their attention to the explicit introduction of technological considerations within the framework of neoclassical production function theory (13). The rather restrictive set of conditions and assumptions required to operate within the framework of production functions has not allowed much progress in this direction. Most studies have tried to explain the nature and magnitude of the "residual," introducing more refined ways of breaking it up. The initial conception was that this residual, or unexplained difference between the output growth and the proportion of this growth supposedly attributable to capital and labour increases, was due to exogenous technical progress which depended on factors that could not be incorporated into the model. Furthermore, technical progress, conceived as a residual factor, was initially thought of as "neutral" in the sense that it was assumed that it did not affect the capital/labour ratio (14). Subsequent formulations of the production functions, and in particular the introduction of constant elasticity of substitution (CES) production functions, allowed the model to approximate reality (represented by statistical history) more closely (15).

Another set of developments in this direction emphasized the importance of technical progress embodied in capital - the embodiment hypothesis - differentiating among the various vintages of machinery that incorporate different levels of technical progress. The hypothesis was that if new technical knowledge can only be embodied in capital goods, then more recent additions to the capital stock must be weighted more heavily than earlier additions, which has the effect of increasing the sensitivity of output growth to changes in the capital stock. Hence, investment becomes the main vehicle for technical progress (16). However, investment acts on the absolute level of technology and not on the rate of technical change, which is still considered an exogenous variable not directly linked to previous investments or to capital formation. In fact, these attempts represent a semiendogenous force of technical progress.

It is interesting to explore some of the implications of the embodiment hypothesis, particularly the contradictory relationships that emerge between technical progress and the rate of obsolescence. The greater the speed of introduction of new machinery, the greater the growth of output. The rate of depreciation affects the speed of introduction of new machinery, thus reducing production costs and raising average productivity, although it also results in the relative economic disappearance of old machines, thereby decreasing the stock of capital. The resulting effect will depend on the relative velocity of these two phenomena, which would also provide a rationale for accelerating the speed of obsolescence and transferring relatively obsolete machinery to other areas, such as the developing regions.

Other ramifications of the production function theory attempt to explain the origin of the rate of technical progress using the "induced" technical progress models (17). The assumption here is that the economic life of equipment comes to its end when the per capita productivity of old machines becomes lower than the wage rate, for wages increase jointly with the introduction of new and more efficient equipment. This assumption implies that the economic life of certain production equipment would be lengthened by transferring it to low-salary locations, such as developing countries. It is also stated that technological knowledge is acquired training and a function of

the production level achieved within the particular working environment. The significant issue in these studies is that in attempting to explain the origin of technical progress the analysis takes into account the problems of generating technical improvements in addition to discussing their impact. They examine not only total investment but also its composition, for some types of investment (such as R&D) accelerate technical progress more than others.

The key ideas that can be drawn from the theory of induced technical progress and related developments can be summarized as follows (18):

(1) All technology is dated and localized; its degree of optimality depends on the specific environment in which it is used.

(2) The key problem is the production or generation of techniques and not so much their use (importation, transfer, assimilation, and adaptation).

(3) The generation of techniques depends on the level and the structure of the general productive activity of the system.

(4) The growth of output depends on the speed of technological innovation, which, in turn, is fed by a higher rate of equipment depreciation.

Another attempt at dealing with the impact of technical progress on production consisted of the explicit introduction of the inventive process through the use of the "invention possibility" function, which is made part of the conventional production function (19). The invention possibility function, which denotes the effect of research on the productivity of capital and labour, is supposed to be multiplicative (and hence neutral) in increasing productivity. The introduction of this new function permits the theoretical analysis of optimum levels of investments in research, but it does not succeed in making production function theory any more useful for policy purposes.

International Trade and Technical Progress

The main ideas on international trade that were put forward by the neoclassical school are strongly related to the expansion of the capitalist system of production at the world level and the corresponding insertion of the less developed countries into the international division of labour. Starting from the classical theory of international trade developed by Ricardo and improved by Mill, subsequent theorists became concerned about the reasons for the existence of comparative advantages in a world where the initial suppositions of the classics (climate and other advantages due to the physical environment) have been superseded by the transition from predominantly agricultural economies to industrial ones. Heckscher (20) and Ohlin (21) provided a model of international trade where it was assumed that the same technology is available all over the world and that there are no technologically derived economies of scale, meaning that production technology could be made to operate with the same efficiency for any scale of output. Given that different industries require capital and labour in different proportions, those countries with large amounts of labour relative to capital will tend to specialize in labour-intensive goods, while countries where capital is relatively more abundant will do the opposite. International trade will arise and a mutually profitable exchange of labour-intensive for capital-intensive goods will take place. This implies that the relative endowments of capital and labour will determine the direction and nature of trade. Samuelson (22) subsequently added his theorem on factor price equalization to this theory.

It has been pointed out that "the assumptions of the Heckscher-Ohlin model are designed to eliminate the possibility of trade occurring due to technological differences between countries, in the form either of inherent differences in technology or of differences associated with varying capacities of countries to exploit a commonly available technology" (23). This assumption may have been valid in the relatively simple industrial world of the last century when production techniques were simpler and easier to master, but it is clearly inadequate at present.

The possession of superior production technology and highly developed technological capabilities constitutes an additional source of comparative advantages above and beyond those conferred by the physical environment and by the relative endowment of capital and labour resources. Posner (24) proposed a model that incorporated technologically derived advantages into a dynamic theory of international trade, demonstrating how technological innovation could create a comparative advantage that had not previously existed. He also postulated that the initial advantage thus

obtained would gradually be eroded by the spread of the new technique through imitation. This theory was refined by Hufbauer (25) and other economists in Britain who differentiated between trade arising out of technological advantages and out of relative factor costs.

However, according to Johnson (26), "the theory suffered from an absence of explanation of why technological innovations occur in some countries rather than in others. The explanation was left at the level of an unexplained decision to invest resources in research."

The "product cycle" theory of Vernon (27) sought to provide answers to the questions of why an innovation emerges in one country and why it is gradually transferred to other countries. According to Vernon, because the innovator has an initial monopoly and because the demand for the new product is likely to be relatively inelastic, the cost of production will not initially be a major factor, and hence he can afford to invest in its development. Also, the development of a new product requires a close interaction between the innovating enterprises and the suppliers of production equipment and machinery. For these reasons, an innovation will take place in the country for whose market it is designed and not elsewhere.

After the introduction of a new product, it will be exported to other countries where a market exists for it, giving rise to a "technological gap" trade. However, as demand grows in other countries and the product becomes known, there will be a tendency to transfer its production to lower-cost locations, either to the foreign country where a market was initially created by exports, or to other places for export back to the country where the original innovation was made. This process of transfer of productive facilities will be associated with the transition from "new" to "standardized" products, while potential competition increases the elasticity of demand, thus making low-cost production increasingly important.

Historically, the classical and neoclassical arguments of the theory of international trade have been used as justifications for the pursuit of free trade policies in the context of expansion of the capitalist system of production. The reasoning could be summarized as follows. Each country should specialize in the production and export of commodities to be determined on the basis of the production factors that it has available in abundance and that allow it to obtain the maximum benefits from its resource endowments. If all countries were to act this way, their productive resources would be used more efficiently, thanks to an international division of labour arising spontaneously out of rational behaviour. The world market would be a complex of reciprocally advantageous trade deals from which all countries would benefit and in which their interests would be harmonized. Furthermore, the argument also postulates that trade taking place under these conditions would lead to the gradual elimination of the differences in economic development prevailing among countries.

However, the historically observed facts on the expansion of trade do not support the postulates of this theory and point in a different direction. Differences among some regions and countries have diminished, primarily as a result of the international expansion of the capitalist system, but at the same time this process has led to an increase in unequal development for other regions and to an absolute transfer of surplus from the developing areas of the world to the industrialized ones (witness the arguments on the deterioration of the terms of trade) (28). While it cannot be ignored that comparative costs play an important role in international trade, neither can it be ignored that trade flows have been imposed and controlled by the industrialized nations to their own benefit. This has not been considered by neoclassical economists primarily because they tend to identify production costs with merchandise costs; this implies considering profits as the remuneration for a given production factor and it ignores the fact that the price at which commodities are traded significantly exceeds production costs, leading to an international transfer of surplus. This phenomenon is increased by the monopolistic domination of production and markets and has been underestimated by neoclassical economists.

In reality, the actual conditions under which trade takes place differ sharply from the ideal conditions implied in the neoclassical arguments in favour of free trade and in the assumption of free determination by each country of its "advantageous" activities. In a critical review of advances in the theory and empirical analysis of trade, Johnson mentions some shortcomings of the traditional neoclassical school:

"The fundamental problem, the conflict between empirical findings and the

theoretical models, can be seen in part as a continuation in the international trade field of the debate begun in the 1930's over the issue of monopolistic as contrasted with perfect, competition - with the important difference that monopolistic competition is now viewed as a rational corollary in the evolution of technology in a free enterprise system rather than as a manifestation of consumer irrationality. The new empirical research stresses the influence on international trade patterns of factors determining monopolistically competitive ability - technological leadership, economies of scale, and product variation (non-standardization). The orthodox theoretical tradition stresses differences in the classical determinants of wealth - specifically, capital per head - on the assumption of a broadly competitive international economy"(29).

The contributions of both Posner and Vernon begin to introduce these issues into the theory of international trade, although they fall short of examining the wide-ranging implications of technologically determined advantages, coupled with a high degree of monopolistic control over production and markets, for the developing countries. The capacity to create comparative advantages as a result of technical innovations and to transfer them rapidly is used to maintain and create new opportunities to enhance monopolistic control. Less developed countries, lacking such technological capacity, have no alternative but to be exporters of primary products or, in certain cases, to assemble parts and components imported from the industrialized countries, thus becoming satellites or workshops of enterprises from the industrialized world.

Schumpeter's Theory of Innovation

Although Schumpeter remains within the conceptual framework of neoclassical theory (or rather, he supports some of the postulates of the classical economists like Smith, Ricardo, Walras, and Marshall), his thoughts on the instability of capitalism and on the central role that innovations play in creating such instability succeed in expanding greatly the scope of the neoclassical approach and its ability to understand the processes of economic evolution and technical change.

Schumpeter does not take issue with the traditional theory of Walras or Marshall; he considers it useful provided it is confined to the analysis of stationary or "steadily growing" processes where any disturbances that may enter are handled by what he calls "passive adaptation," that is, "adaptation within the fundamental data of the system" (30). However, he finds Walrasian-Marshallian theories insufficient when the business community under consideration faces new possibilities for action, which are as yet untried and about which even the most complete command of routine teaches little. He develops his theory of innovation to handle situations where the course of technical progress introduces disturbances, leading to a type of adaptation that consists of "changing the internal characteristics of the system."

Schumpeter defines innovation as "the setting up of a new production function" and introduces it as the main cause for the waves and disequilibria that characterize the capitalist system. To him "what dominates the picture of capitalistic life and is more than anything else responsible for our impression of a prevalence of decreasing cost, causing disequilibria, cutthroat competition and so on, is innovation, the intrusion into the system of new production functions which incessantly shift existing cost curves."

Schumpeter's theory of innovation postulates three basic assumptions. First, innovations entail the construction of new plant and equipment - or the rebuilding of old plant - requiring noneligible time and investment. This implies restricting the concept of innovation to a change of the first order in the production function. Second, every innovation is embodied in a new firm founded for that purpose, primarily because "no firm which is merely run on established lines, however conscientious the management of its routine business may be, remains in capitalistic society a source of profit, and the day comes for each when it ceases to pay interest and even depreciation" (31). Third, innovations are always associated with the rise to leadership of new men, including the case where a new man takes care of an old firm (which would be an exception to the second assumption). It is particularly interesting that Schumpeter also considered the case of giant corporations that are "shells within which an ever-changing personnel may go from innovation to innovation." In his view this process would become more important with the passage of time and would replace the system of "competitive capitalism" with a system he called "trustified capitalism" (32).

In his analysis of innovation Schumpeter awarded a most important role to the entrepreneur, whom he distinguished from the manager. For him "it is leadership rather

than ownership that matters," and consequently his economic theories put substantial weight on sociological factors (33).

In putting together the action of the entrepreneur, the process of innovation, and the evolution of capitalism, Schumpeter took a very important step toward a clearer understanding of the relation between technology and economic evolution, thereby enabling the neoclassical school to proceed beyond the framework provided by static analysis. Nevertheless, it is interesting that although he was confident that the disturbances brought about by technological innovations would not destroy what he considered the inherent economic instability of the capitalist system, he thought the social implications of capitalism would lead to its eventual replacement:

"...capitalism, whilst economically stable, and even gaining in stability, creates, by rationalizing the human mind, a mentality and a style of life incompatible with its own fundamental conditions, and will be changed, although not by economic necessity and probably at some sacrifice of economic welfare, into an order of things which it will be merely a matter of taste to call socialism or not" (34).

The Factor Proportions Problem and the Choice of Techniques

Another set of developments that uses the instruments of neoclassical theory to examine the problem of technology and its relation to development focuses on the availability of factors of production, their relative prices, the existence of techniques that use these factors in different proportions, and the process of choosing techniques. In its simplest theoretical formulation the model uses a two-factor (capital and labour) production function as the basic tool. It is postulated that for a given quantity of output and a given relation between the prices of capital and labour, there exists an "optimal combination" of these two factors, i.e., a production technique, that should be used to minimize costs. Assuming the choice is rational, departures from the optimal combination are explained in terms of distortion of factor prices from the "true" prices that would reflect their relative scarcity, and also in terms of the inexistence of techniques that would correspond in practice to the theoretical optimum.

This problem was first brought to the attention of development economists by Eckaus (35), who proposed a set of hypotheses to explain the existence of unemployment and underemployment in developing areas in terms of "the factor proportions problem." He distinguished between two types of explanations that may be derived from this point of view:

"The first type assumes that available technology would permit full use of the working force at some set of relative prices and finds the source of unemployment in various types of 'imperfections' in the price system. The second type suggests that there are limitations in the existing technology or the structure of demand which lead to a redundancy of labour in densely populated underdeveloped areas" (36).

The "relative factor price distortions approach" postulates that the main reason for the choice of inappropriate technologies in less developed countries is that they have pursued economic and social development strategies that have unduly cheapened the cost of capital in relation to labour costs. Overvalued exchange rates, tax and credit subsidies, and excessively protective tariffs against competitive imports have artificially lowered the cost of capital to investors, while social policies, the pressure of trade unions, and various welfare measures (usually adopted in imitation of developed countries before the economic system is capable of supporting them) have raised the cost of labour far above its "natural cost." The argument concludes that capital-intensive techniques have been encouraged and labour-using ones discouraged, and that under these circumstances rational entrepreneurs would tend to import more capital-intensive techniques than if the relative factor prices had reflected the "true" or "socially correct" prices based on the relative abundance or scarcity of production factors.

Felix (37) has made a thorough criticism of this approach in the Latin American context. After reviewing the main claims and policy implications of the problem of factor proportions from the relative price distortions point of view, he concludes:

"The main virtue of the approach is that it emphasizes...that the inappropriate choice of technology in Latin American countries reflects market forces that bias entrepreneurial decisions in a socially suboptimal direction, rather than merely an inadequate inflow and dissemination of technological information from abroad.

The critical deficiency of the relative price distortion approach is its underlying theoretical model. The model is based on institutional and behavioural assumptions that abstract from such central real world phenomena as: uneven capacities to generate technology between countries, increasing economies of scale, uncertainty and uneven financial constraints on accumulation between small and large firms, oligopolistic competition, and plastic consumer preferences. It is nevertheless the basic normative model which guides the global prescriptions for optimizing technological borrowing by peripheral countries through eliminating relative price distortions, even though the model provides no analysis of either the complex forces, other than the relative prices, that govern technological progress in the centre countries, nor of the sociopsychological forces, other than the relative prices and incomes, that influence consumer choice in the peripheral countries" (38).

The "lack of appropriate technologies" suited to the conditions of less developed countries has also received wide attention in the literature. Eckaus himself pointed out the need for research into the problem of finding technologies "adapted to the conditions of underdeveloped areas" (39). A plethora of concepts and terms, such as "intermediate, labour-intensive, adequate, soft, progressive, low-cost," etc., have been proposed to characterize the new technologies, which do not exist or have fallen into disuse, and which should be generated and utilized, in the less developed areas (40). One of the most ardent proponents of the use of such technologies, particularly in the rural areas, is Schumacher (41), who considers that the main task of development is "to bring into existence millions of new workplaces in the rural areas and small towns... modern industry, as it has arisen in the developed countries, cannot possibly fulfill this task...it has arisen in societies which are rich in capital and short of labour and therefore cannot possibly be appropriate for societies short of capital and rich in labour" (42).

Schumacher goes beyond the neoclassical framework in his analysis of appropriate technologies, although he uses some concepts from this school. He defines the main task of development, emphasizing the rural areas, in terms of four propositions:

"First, that workplaces have to be created in the areas where the people are living now, and not primarily in metropolitan areas into which they tend to migrate.

"Second, that these workplaces must be, on average, cheap enough so that they can be created in large numbers without this calling for an unattainable level of capital formation and imports.

"Third, that the production methods employed must be relatively simple, so that the demands for high skills are minimized,...

"Fourth, that production should be mainly from local materials and mainly for local use. These requirements can be met only if there is a 'regional' approach to development and, second, if there is a conscious effort to develop and apply what may be called an 'intermediate technology' (43)...Such an intermediate technology would be immensely more productive than the indigenous technology (which is often in a condition of decay), but it would also be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry" (44).

The question of convergence between the factor endowment of a particular country and the utilization of factors in productive activities, which is in essence the problem of availability and use of appropriate technologies, has also been considered by several authors as the central problem in socioeconomic development. For example, Lange (45) defines an underdeveloped economy as one in which the total stock of capital is insufficient to absorb the labour force using existing modern techniques of production. Unless new "appropriate" technologies become available, these countries will either have to employ the modern techniques, use up all their limited capital and then face massive unemployment, or use traditional low-productivity techniques that do not generate enough surplus to employ an expanding labour force at an adequate level of income. In either case the basic problems of underdevelopment remain. An African economist, Onyemelukwe (46), has recently gone as far as proposing that the "key to development theory lies in the right application of factor proportions - capital, labour and raw materials," and that:

"The adoption of factor proportions which are in line with the surrounding factor endowments is a necessary condition for a development process. It follows that adoption of factor proportions which are out of line with those of the surrounding area might in itself choke off mass participation and lead to a development process which is

controlled either by outsiders or by government or both" (47).

Thus the evolution of concepts regarding the problem of factor proportions, insofar as they deal with the nonavailability of techniques, transcends the framework of traditional neoclassical analysis. Furthermore, although the original formulation referred to the issue of unemployment, recent developments have examined the choice of techniques from a broader point of view, making it one of the key issues in the study of development processes (48).

THE HISTORICAL PERSPECTIVE OF ROSTOW'S STAGES OF GROWTH THEORY

The interrelations between science, technology, and economic growth have also been studied from a historical perspective, and although many alternative ways of examining these interrelations have been offered, it is interesting to review Rostow's concept of "stages of growth" because of the controversy it has generated and the central role it awards to technological change.

Rostow's intention in formulating his theory was to provide a description and an explanation of the process of economic growth. In doing so he proposed a linear interpretation of economic history, postulating five stages through which all countries must pass before reaching the levels of the present advanced societies: the traditional or preNewtonian stage; the preconditions for take-off; the take-off into self-sustained growth; the drive to technological maturity; and the age of mass consumption (49).

In the first stage, traditional societies evolve within the limits of productive activities based on preNewtonian techniques and attitudes. There exists a ceiling to the level of per capita production that can be obtained. These limits to agricultural production, to industrial output and employment, to the level of population that can be sustained, and so on, arise because access to modern scientific and technical possibilities cannot be secured in a regular and systematic way. Newton's concepts are singled out by Rostow because they represent a basic psychological change whereby man accepted the view that the physical world is capable of being understood and manipulated in terms of relatively few stable rules.

The second stage, the preconditions for take-off, is considered as "the period during which a traditional society becomes sufficiently modernized in all its dimensions to undertake the first serious, even if limited, phase of the enterprise which, more than any other, is the hallmark of modernity; that is, industrialization, including, of course, regular innovation in agriculture, transport, communication and other services" (50). This transition to modernity is punctuated by the acceptance of the Newtonian view of the world, the emergence of a new type of entrepreneur willing to invest in nontraditional activities such as industry, and the existence of a minimum stock of social overhead capital. It is also postulated that "society must mobilize from its own resources (and, where possible, from capital imports) the materials, labour, and skills required for a massive buildup of social overhead capital, notably to provide education, transport and energy" (51).

The take-off into self-sustained growth is the third stage of Rostow's theory. Initially he defined the take-off as "the interval during which the rate of investment increases in such a way that real output per capita rises and this initial increase carries with it radical changes in production techniques and the disposition of income flows which perpetuate the new scale of investment and perpetuate thereby the rising trend in per capita output" (52). Rostow points out that the take-off is confined to relatively few sectors, and possibly to limited regions within a nation, and that modern industrialization expands rapidly during it. Furthermore, this process of industrialization lifts the restraints on income per capita built into the dynamics of the preNewtonian world. Although Rostow considers the problems involved in a possible deceleration of growth in particular sectors of industry, he also points out that the "flow of modern science and technology may offer the potentiality of fending off Ricardian diminishing returns indefinitely," and thus concludes that "the experience of take-off appears, on present evidence, to be a definitive transition, like the loss of innocence."

The following stage of the drive to technological maturity is defined as a period, considerably longer than the take-off, during which the economy begins to absorb and apply more or less fully what the unfolding stream of science and technology can provide. The basic and capital goods industries take the lead, agriculture becomes modernized, the educational system expands to meet the needs of industrialization, and

an efficient communications network is established. The economy expands and finds its place within the international scene, although this expansion may take place at the expense of less advanced societies.

Finally, the age of mass consumption completes this evolutionary scheme. Industrial leadership passes on to the durable consumer goods industry - with the automobile becoming the key symbol - and to the provision of services. Income per capita grows so as to allow a large segment of the population to move beyond the satisfaction of basic needs, thus changing the structure of the labour force and its special distribution. Society stops accepting as an article of faith the need to expand modern technology and begins to consider it as a subordinate objective. The welfare state emerges in full force and becomes the main political manifestation of a society that has moved beyond technological maturity. Rostow is unclear about the possible subsequent evolution of societies beyond the age of mass consumption, although he visualizes a stage where the main emphasis is placed on the "search for quality," which he defines as the "enrichment of private life."

The central role awarded by Rostow to technological change, and to industrial technology in particular, has led to attempts at defining parallel concepts for science and technology. For example, a summary of the long-term plan for scientific and technological development of Korea (53), drafted in the late 1960's, linked the take-off stage with the dependence on production facilities, techniques, and plant engineering in advanced countries, and with the growth of import substitution industries. The drive to technological maturity was associated with the expansion of plant engineering capabilities and metal-mechanic industries, with the transition from capital equipment imports to imports of technology, with at least 50% technological self-sufficiency in productive techniques for light industries, and with a continued import of facilities, techniques, and services for heavy chemical industries and high-technology industries such as electronics. Finally, the age of mass production was associated with technological self-sufficiency in light industries, with the import of some facilities and techniques for heavy chemical industries, with the expansion of technical and engineering exports, with the promotion of international confidence in Korean industrial standards, and with an increase in the sales of patents and technical know-how.

Rostow's theory of stages of growth has been widely criticized. The linear model of development, which postulates a unique path through which all countries must proceed before becoming "advanced," has been considered unacceptable for most developing countries at present. The parallels Rostow draws between the historical evolution of the presently industrialized countries and the developing ones have been shown to be inadequate in many instances (54). Of particular interest is the general warning that Kuznets makes about the validity of comparisons between the early stages of development of industrialized societies and the present condition of the less developed countries:

"Both the absolute and relative economic position, as well as the general cast of the immediately antecedent history, of the now developed countries in their pre-industrial phase were cardinally different from the economic position and the immediate historical heritage of the underdeveloped countries of today. It is, therefore, far from safe to extrapolate economic or demographic aspects from the earlier records for the developed countries to current and prospective levels for the underdeveloped" (55).

In his Nobel prize lecture, delivered in 1971, Kuznets emphasized the role of technology in creating the differences between the earlier stages of development of industrialized countries and the present situation of the developing ones:

"...the stock of material and social technology that can be tapped by less-developed countries today is enormously larger than that available in the 19th and even early 20th centuries. But it is precisely this combination of greater backwardness and seemingly greater backlog of technology that makes for the significant differences between the growth position of the less-developed countries when they were entering the modern economic growth process" (56).

"...a substantial economic advance in the less developed countries may require modifications in the available stock of material technology, and probably even greater innovations in political and social structure. It will not be a matter of merely borrowing existing tools, material and social, or of directly applying past patterns of growth, merely allowing for differences in parameters" (57).

Therefore, although Rostow's concepts provide an appealing and apparently simple blueprint, great caution should be exerted in extrapolating his historical

findings to examine the present condition of less developed countries and derive policy recommendations (58).

THE "STRUCTURALIST" VIEW OF THE U.N. ECONOMIC COMMISSION FOR LATIN AMERICA

The approach to economic development theory and strategy of the U.N. Economic Commission for Latin America (ECLA) and its most representative economists (Prebisch, Pinto, and Furtado, among others) emphasizes the structural conditions that characterize the underdevelopment of Latin American countries and that are the result of their historical evolution and insertion into the world economy (59).

ECLA's conceptualization of the processes of economic development and underdevelopment differs from those of the neoclassical school and from the historical deterministic approach of Rostow. In contrast with the neoclassical way of theorizing, ECLA's starting point is with historically observed facts and present conditions, i.e., things as they are, rather than things as they should be, derived from theoretical models. While the historical context is taken into consideration explicitly, this is done in a way radically different from Rostow: instead of describing a linear process followed (or to be followed) more or less independently by each country, the ECLA school emphasizes the structural economic interrelations among developed and less developed countries, showing that the development of some countries has taken place at the expense of the underdevelopment of others (60). Furtado summarizes this point of view in the following terms:

"As a consequence of the rapid spread of new production methods from a small number of centres radiating technological innovations, there has come to existence a process tending to create a worldwide economic system. It is thus that underdevelopment is considered a creature of development, or rather, as a consequence of the impact of the technical processes and the international division of labour commanded by the small number of societies that espoused the industrial revolution of the 19th century. The resulting relations between these societies and the underdeveloped areas involve forms of dependence that can hardly be overcome...underdevelopment cannot be studied as a 'phase' of the development process since such a 'phase' would be overcome if certain factors came into play simultaneously. And, since the underdeveloped economies are contemporaries of - and in one way or another, dependent on - their developed counterparts, the former cannot retrace the experiences of the latter. Therefore, development and underdevelopment should be considered as two aspects of the same historical process involving the creation and the spread of modern technology" (61).

Originally, in the work published in the 1950's ECLA economists gave primary importance to the type of participation that Latin American economies had in the international division of labour, as shown by their critical analysis of the deterioration in the terms of trade and the use of concepts such as "dependence, centre, and periphery." Later, in the 1960's ECLA devoted most of its analysis to the internal problems of development, such as the bottlenecks for the expansion of import substitution industrialization. It was recognized that changes in the internal structure of production usually emerged as a response to problems posed by the type of participation of the developing countries in international trade, and the primary concern was to rearrange the internal productive machinery to participate in international trade on a more profitable and equitable basis. However, the nature of the international capitalist division of labour was not generally questioned by the ECLA school, and thus the model proposed was one of inward development within the framework of capitalism.

Though a critique can be made of ECLA's interpretation of the historical evolution of Latin American economies, the characterization has been widely accepted. ECLA divides Latin American economic history into four phases as follows: the phase prior to outward development, which lasted until the middle of the last century; the phase of outward development and integration in the international capitalist division of labour, approximately from 1870 to 1930; the phase of inward development, based primarily on import substitution industrialization and spanning approximately from 1930 to the middle of the 1950's; and the phase of stagnation, covering basically the 1960's.

ECLA points out that outward growth depends on the dynamism of the demand for export products, which conditions the expansion of the exporting sector and hence the

growth of internal production and employment. Export activities depend on the nature of available resources, which would also determine the type of technological imports that are necessary (equipment and machinery, know-how, technical personnel), as well as the degree of local adaptation and assimilation of technologies. Given the incipient character of the scientific, industrial, and technological infrastructure, these adaptations are generally the result of isolated efforts, and technological requirements are mostly met from imports, which will usually be capital intensive. This creates a pattern of technological "enclaves" with insignificant internal multiplying effects. It is also argued that the narrowness of the domestic market is related to the predominance of outward-oriented demand in the sense that the available surplus is either sent abroad directly or used to increase and diversify consumption by the local wealthy minority. Furthermore, the export sector attained a high productivity and profitability due to the extremely favourable conditions granted by the state. Resource allocation policies were designed to provide the infrastructure for outward growth (public utilities, railroads, roads, etc.), and the construction sector - with its easily acquired and mastered technology - showed great dynamism.

ECLA concludes that any effort to expand and diversify internal production - that is, any effort toward industrialization - would imply a high level of accumulation that is far beyond the resources obtainable from the export sector, which is continuously vulnerable to fluctuations in prices and foreign demand. ECLA holds that because of the limitations of the external sector in creating investable surplus, and because industrial expansion and diversification require the use of increasingly complex and expensive technologies, it was difficult for the impulse for industrialization to arise internally. External events, such as the crisis of the 1930's and World War II, provided the necessary stimulus. The crisis of the 1930's constricted the exports of Latin American countries, reducing their capability to import and forcing them to develop an internal productive machinery. World War II increased export earnings and limited import capacity, making feasible the development of domestic production. In both cases, industrialization appears in the ECLA analysis as a response and as an effort to substitute goods that cannot be imported.

The way ECLA links external demand to the internal market and the technological implications of its expansion make it possible to conceive the import substitution strategy. ECLA's analysis then focuses on the internal conditions and restrictions that hinder industrial development, while at the same time it describes the favourable foreign junctures that should allow industrialization to take place.

For ECLA, technology ranks highly among the factors that shape the import substitution process. It says that the type of technical progress prevailing in industrialized countries explains why the income elasticity of its demand for primary imports - that is, the demand for export products from developing countries - is less than one. Thus, when the income of developing countries increases at a rate equal to, or higher than, the rate in developed countries, imports by developing countries (durable consumer, intermediate, and capital goods) tend to grow faster than their exports (raw and semiprocessed materials). The increased demand for imports, determined by the type of industrialization, requires identifying those imports that must be substituted by domestic production so as to be able to import the rest. The ECLA analysis is however not applicable to all types of raw materials exported by Latin American countries, food products in particular.

The ECLA theorists postulate that import substitution first concentrates on technologically simple goods (especially light industry) because of unawareness or lack of knowledge about more advanced production technologies and also because of the restrictions imposed by the nature of the internal market. Thus, in the first stage of the import substitution process (called the stage of "easy" substitution) the percentage of imported consumer goods decreases at the same time that industrial development is limited to certain specific branches and industries.

ECLA acknowledges that the import substitution industrialization pattern has increased the requirements for imported technology, which is capital intensive and thus responsible for the small labour absorption capacity of industry. To generate sufficient employment under such conditions would demand a considerable internal investment and capitalization effort, which would be strongly handicapped by the low levels of domestic income and savings. On the other hand, the indivisibility of productive techniques makes it mandatory to produce at scales higher than those strictly required by the narrow local markets. Thus there appears a lack of

compatibility between the technologies used and the supply of labour, as reflected in high unemployment and underemployment levels, high rates of idle installed capacity, and the relative lack of financial resources for further investment (62).

Technology is one factor, among others, which contributes to the external bottleneck that hinders the import substitution process. As industrialization progresses and with it, import requirements, it is necessary to broaden the scope of substitution to durable consumer goods, intermediate goods, and capital goods. This is the so-called "difficult" substitution stage, not only because of the greater complexity of the technology incorporated in such goods, but also because they demand scales of production and investment that clash with the narrowness of the markets of developing countries (perhaps with the exception of countries such as Argentina, Brazil, and Mexico). Many of these goods then continue to be imported, making the problem of reduction of the compressible import margin more serious, and the overall economy more vulnerable to fluctuations in the price levels and the demand for exports. Therefore, as a result of a more complex set of internal factors, there arises a similar problem to the one that resulted from the outward growth phase.

ECLA postulates that the deepening of inward growth is endangered by the survival of rigid and archaic agricultural and social structures, which, among other things, are responsible for the limited capacity for internal generation of savings and investment funds. For ECLA, imbalances in the agricultural sector apparently do not have a technological origin but rather are the result of the prevailing land-owning and tenure system: large landholdings (latifundia) underutilize land and labour; minute landholdings (minifundia) put intrinsic constraints on capitalization and increases in productivity. Therefore, sources of internal financing cannot replace financing from the external sector. ECLA recommended the implementation of agrarian reforms tending to make agriculture an effective foundation for industrialization. It suggested the implementation of social changes (redistribution of income, increased employment, deconcentration and decentralization of the productive machinery, etc.) that would encourage the development of productive forces and allow the acceleration of internal accumulation. All of this assumed a state capable of planning and promoting development. Thus, this school of thought provided an explanatory base for various reformist and nationalistic ideologies that aimed at modernizing the economy by developing the local bourgeoisie.

Contrary to ECLA's expectations, the outward growth phase has continued alone or overlapping with inward growth processes, for it is clear that all the Latin American countries have continued to depend on the export of raw materials during the past three decades. Therefore, the outward development stage did not end in the 1930's and no country has been able to sever its primary export links with the international system. In the mid and late 1960's the import substitution strategy linked to inward growth began to be questioned (63) and a renewed concern with employment problems was voiced (64).

The concept of "enclave" and its subsequent derivations are of particular importance for technology. Initially it differentiated between a technologically modern export sector and a traditional sector linked to the domestic market. This led later to the concept of "technological dualism," which refers to the coexistence, both within and between economic sectors, of productive activities and units using advanced techniques with others using archaic or obsolete technologies. The former were, in some way or other, linked to foreign markets or foreign sources of technology, while the latter used almost exclusively productive techniques of local origin.

The concept of technological dualism was later abandoned in favour of the more realistic and complex concept of "structural heterogeneity." According to Pinto:

"...the emerging situation has meant leaving behind - at least for the relatively more developed economies - that schema of technological dualism which could have been characteristic of the past, and opening the way to a much more complex reality of structural heterogeneity...As an inevitable consequence of the particular structural heterogeneity - and although, indeed, this is not the only factor influencing this matter - the fruits of technical progress have tended to be hoarded primarily by those who have greater organic links with the productive and territorial nuclei of the modern strata" (his emphasis) (65).

As a consequence of the financing needs of Latin American countries, of the nature of the import substitution industrialization process, and of the expansion of multinational corporations (MNCs), foreign investment began to play a dominant role in

the dynamic sectors of Latin American economies during the 1960's. The implications of this situation have been examined carefully by ECLA in its 1973 "Economic Study of Latin America." However, the most interesting studies of the impact of MNCs in Latin America have been made by other economists who are of the "structuralist" school of thought but who have not been associated with ECLA for a long time. Sunkel (66) has postulated that the national disintegration process now taking place in most Latin American societies is the reflection of a broader trend toward transnational capitalist integration, which links the elites of the developing countries with the central countries. In this process of transnational integration and national disintegration, MNCs play a major instrumental role, based primarily on their control of technology and of the access to markets (67). Furtado (68) holds that the capacity to control technical progress and to impose consumption patterns has been the decisive factor in the structuring of the productive system of the dependent countries. In the new international economy that is now emerging with the forceful expansion of MNCs, the main characteristic is that technology, materialized in equipment and the design of consumer goods, tends to be less and less the object of market transactions and is transferred internally among the various component firms of the MNCs. Given the imitative pattern of development of the peripheral countries, particularly with regard to consumption, the access to technical innovation is a necessary condition for their dependent growth (69).

Furtado has also emphasized the importance of technology in the process of development. In the concluding chapter of his book "Economic Development of Latin America," he attaches particular significance to:

"Reconstruction of economic structures with a view to intensifying the assimilation of modern technology in all productive sectors...

"Formulation of employment policies capable of putting an end to the present process of growing social marginalization.... The solution to this complex problem calls for a minimum of autonomous technology which the countries of the region at present do not possess.

"The achievement of a minimum of technological autonomy...Given the peculiarities of the region's natural resources, particularly in the case of the tropical and subtropical areas, and in view of the sui generis aspects of the economy, Latin America's development calls for a concerted effort in promoting technological research and the background sciences required to consolidate and develop research findings" (70).

The structuralist school of thought is practically the only descriptive and explanatory construct offered by the less developed countries to examine the problems of development and the role that technology plays in it (71). Its relevance to the African and Asian countries has been demonstrated through their influence on intellectual developments and on economic policy (72). However, it is pertinent that the ECLA version of the structuralist school did not suggest radical alternatives to the present mode of insertion of the developing countries into the international economic system. ECLA has taken an economic point of view without paying much attention to the connection between productive structures and internal sociopolitical structures. Other writers of the structuralist school of thought, Furtado for example, have given considerable attention to these issues, which were largely ignored by ECLA.

THE CONCEPTS OF DEPENDENCE AND TECHNOLOGICAL DEPENDENCE (73)

As the implementation of import substitution policies proceeded in Latin America in the 1960's according to the strategy proposed by ECLA, and as direct foreign investment began to play an increasingly dominant role in economic growth, the problem of balance of payments became more acute. There was also a slack demand for primary export products, and the problem of unemployment emerged in full view. Nothing suggested an improvement in regressive forms of income distribution, agrarian reform was carried out timidly and did not produce the anticipated results, and the modernization of productive and social structures proposed by ECLA appeared insufficient to deal with the "stagnation" of Latin American development.

The lack of any long-term prospect for growth and development, and the evidence that national entrepreneurs were unable to develop on their own a capitalist economy as happened in Europe a century earlier, prompted a critical revision of the structuralist

ideas and led to the emergence of dependency theory. While preserving the framework of centre-periphery relations borrowed from the ECLA structuralist school, the theory of dependence attempts to go beyond the improvement of economic conditions through modernization, seeking to explain the mechanics of underdevelopment and to establish the basis for a new theory of development.

There are indisputable and sometimes fundamental differences among the views of the leading dependency theorists (Cardoso, Gunder Frank, Dos Santos, Sunkel and Paz, Quijano, and Kaplan, among others). Nevertheless, common roots can be found in the criticism of ECLA's structuralism in the context of economic stagnation, and in the Marxist critique of capitalist development, in particular the theories of imperialism. It is interesting that the majority of the dependency theorists were sociologists trying to go beyond the strictly economic perspective of ECLA's structuralist views (74).

Dependence refers to a type of domination/subordination relationship between productive structures in capitalist regions or countries of unequal levels of development. The theory of dependence states that underdevelopment is not innate to countries but is brought about by the expansion of capitalism, which at a later stage became identified with the growth of multinational corporations.

In opposition to other theories of development, which stress the existence of mechanisms that spread growth automatically (foreign trade, foreign investment, education and manpower training, income distribution, and so on), the theory of dependence emphasizes the existence of structural mechanisms that obstruct economic evolution and prevent society at large from reaping the benefits of economic growth. Such blocking mechanisms would often be the same ones that generate growth in industrialized capitalist economies, but in developing societies they would function in the opposite direction. For example, international trade would act as an "engine of growth" in developed economies, but in developing countries it would be a source of distortions, creating enclaves, leading to balance of payments problems, and promoting imitative consumption patterns.

According to this view, the means of domination may be found in all the economic and social functions that permit the expansion of the capitalist industrialized countries: accumulation of capital, trade, technical innovation, education, and so on. Because these are precisely the mechanisms of economic growth, the theory of dependence postulates that the condition of subordination or domination provides a context that changes the nature of these mechanisms in a perverse way. This leads to the globalization of the concept of dependence, and most authors tend to reproduce statements such as the one made by Aguilar (75): "In the case of Latin America one should speak of a dependence or structural subordination, i.e., a dependence that is economic, technological, cultural, and even military, that deeply influences at the same time the shape of all the socioeconomic structure and that, in particular, conditions many of the main features of the system and the process of development."

Dependency theory also links the external domination of developing countries to forms of internal domination and internalized structures of dependence. Thus the predominance of urban over rural areas in developing countries is seen as the logical translation of external domination, and the local urban bourgeoisie is seen as playing the same role internally that international capital plays in intercountry dependency relations.

The need to make dependency theory more operational has forced students of dependence to focus on particular aspects of the dependency syndrome, leading to studies of trade dependence, financial dependence, cultural dependence, technological dependence, and so on, although always acknowledging the interconnection among these types of dependence and usually attempting to provide a hierarchical framework for their analysis.

Technological Dependence

In the early 1970's with the need to make dependency theory more operational, the concept of technological dependence began to gain wide acceptability. It was postulated that the nature of domination relations between developed and developing countries was moving from the control of primary products for export to the control of productive facilities, to the control of finance, and to the control of technological knowledge as the main vehicle for maintaining the relations of domination. While several of these forms of domination coexisted, a clear trend was seen as emerging in

the direction pointed out. It was further suggested that "in this process of mutation of dominant relations technology has been always behind as a conditioning factor, but it has now finally emerged out in the open, partly because of the internal dynamics of the evolution of the capitalist system, and partly because of the increased control of the less developed countries over the means through which the developed countries exerted their domination in the past" (76).

O'Donnell summarizes the current view of technological dependence as follows:

"...the problem of technological dependence is an aspect or a dimension of the general problem of dependence which manifests itself also in cultural, military and economic aspects among others. Not withstanding this, it is possible, of course, to distinguish in an analytical and empirical fashion the first dimension so as to make it a valid and undoubtedly important object of research....The fact that this distinction is possible does not imply, on the other hand, that the analysis may omit reference to the other dimensions, nor that in the final analysis the whole of these dimensions may not be seen as part of the global characteristics of given societies and the ways they insert in the international context....Technological dependence, like all other dimensions of dependence, implies an asymmetrical relation of power. In this case we are concerned with the power to control the information or the know-how necessary to detect a need, to analyze, evaluate, generate, concretize the production of goods or services which aim at satisfying the needs of a society at a given moment in time, and the necessities of its historical development" (77).

In another study O'Donnell and Linck (78) have systematized a number of issues that are generally raised in relation to dependence, providing an integrated hierarchical framework to examine problems such as foreign dominance of decision making, particularly in the dynamic sectors of the economy, the country's reliance on foreign finance and foreign material inputs, and the overwhelming predominance of foreign technology in the modern sector.

Following a similar line of reasoning Thomas (79) concludes that dependency arises as a result of "the lack of organic link, rooted in an indigenous science and technology, between the pattern of growth of domestic resource use and the pattern of growth of domestic demand."

It is interesting that this preoccupation with the lack of linkage between domestic demand and domestic production is the same problem the ECLA school addressed in the early 1950's. The new element introduced is the belief that indigenous science and technology can provide the missing link, while 25 years ago import substitution industrialization had been heralded as the key solution. This points out the fact that when dependency theoreticians refer to internal phenomena, they resort to the scheme and categories developed earlier by the structuralist school. Perhaps the main difference between these two schools in their conception of technological problems is the emphasis given by dependency theory to foreign investment, which is considered as the transmitter of a whole pattern of technological dependence. The argument states that capital-intensive technologies introduced from abroad, primarily through foreign investment, accentuate production and market concentration, favouring the interests of foreign enterprises that control the necessary capital, technical know-how, and commercialization channels. From this some dependentists conclude that the extraction of surplus assumes the privileged form of profit flows and technology payments.

The introduction of technological issues into the study of dependence helped to draw a distinction between the concepts of control and ownership of productive facilities. It was shown that even though ownership of industry may be in the hands of local entrepreneurs or the state, foreign control could still be exerted through the provision of key technological inputs. In turn, this control of technology would lead to the progressive introduction of other forms of foreign control (financial for example), and in many cases to the outright acquisition of established local enterprises.

Specific studies of technological dependence focused on the drain of foreign exchange it generated, on the distortions introduced to the productive structure through the adoption of unsuitable technologies, on the loss of control by local enterprises over their own operations, and on the segmentation of international markets by the suppliers of technology (80). These studies all provided fairly good descriptions of technological subordination, but they did not provide specific alternatives, except in the form of stressing the need for reforms that would challenge the existing international economic order. It is only recently that the alternatives to dependence,

and to technological dependence in particular, have begun to be articulated as operational strategies.

The alternative to dependence has been postulated in terms of a transition to socialism. Referring to the Argentinian case, O'Donnell and Linck (81) state that this is the only way of getting out of dependent capitalist structures "which cannot cease operating according to a profoundly inhumane scale of priorities" and they suggest the characteristics that an "autonomous socialism" should have. Thomas (82) has developed an economic strategy for the transition to socialism, based on what he calls the two "iron laws of transformation" - converging resource use with demand, and converging needs with demand: "Our basic strategy for transforming (underdeveloped) economies is to plan the convergence of domestic resource use, domestic demand, and needs in such a way as to create the basis for an indigenous technology."

In his conceptualization he comes close to some ideas of Sraffa and the oligopoly theorists who see the choice of products as a basic decision in the strategy of development. Technological issues figure prominently in Thomas's formulation of the strategy of transition to socialism, considered as the only alternative to dependence (83).

The recent importance attached to self-reliance, considered as an alternative to dependence, has also led to attempts at defining technological self-reliance (84). However, because technological dependence does not render itself to be transformed directly into policy recommendations, technological self-reliance has tended to remain at the same level of generality when it is posed as an alternative to it. Nevertheless, there have been some attempts to descend from generalities and to define technological self-reliance in operational terms (85). What remains to be integrated into the theory of dependence, and also into the alternatives of self-reliance and the transition to socialism, is the international strategy that would permit their attainment. The calls for a new international economic order require further elaboration before they can provide an adequate conceptual background for the realization of the alternatives proposed to dependence. Of particular importance in this regard is the expansion of cooperation among Third World countries (86).

THE THEORY OF OLIGOPOLY AND THE ROLE OF TECHNICAL PROGRESS

Starting in the 1930's a group of neoclassical economists challenged the orthodox version of neoclassicism (87). One reason, among many others, for this rupture was the need to incorporate into the analysis the process of industrial concentration that became evident after the end of the last century, which meant the relative decline of capitalist competition and the appearance of large monopolistic or oligopolistic enterprises capable of much greater influence over prices and production levels, and of control over supply and demand forces. At the same time, this implied the disappearance of small enterprises or their transformation into satellites or affiliates of the larger ones.

The theory of oligopoly went far beyond the imperfect competition models, which, in essence, are variations of the basic perfect competition model and consider concentration to be an "aberration" that deviates from the normal capitalist course of events. Oligopoly theory emerged from the confrontation between traditional neoclassical concepts and the new industrial realities of late 19th and early 20th century capitalism. The concentration processes referred to by these theoreticians consist of increases in capital, output, and workers per firm, which would be the result of a grouping of enterprises or industrial plants, or of linking enterprises through equity participation. Concentration permits the grouped enterprises to set a common policy on investments, production, and prices, giving them increased power in the market.

An oligopoly will arise when the minimum average cost necessary to attain an efficient level of production and an optimum utilization of capacity is such that it may only be obtained through relatively high production scales, which require significant initial outlays, which can only be achieved by a limited number of producers in each industry, and which exclude the rest of the producers. This is closely related to the concept of "condition of entry," which refers to the advantages enjoyed by established firms over potential entrants.

For classical economists (particularly Ricardo), technical progress, defined as the introduction of new machines that reduce production costs, should also reduce product

prices. This worked in the competitive environment of early capitalism, which involved minimum average costs associated with relatively small levels of output. But this mechanism does not operate at the monopolistic stage of capitalism, when cost reductions would tend to modify prices only if the monopolist felt he could expand his production in response to demand elasticity so as to maintain or increase his total revenue. For there to be a decrease in prices as a consequence of technical progress, in an oligopoly it is necessary to assume that cost reductions imply a reduction in the prices of variable production factors and that technological innovations are accessible to all enterprises regardless of their size, which are rather strong and unrealistic assumptions.

What happens in most cases is that the prices remain rigid and revenues vary as a result of technical progress, leading to an increase in the profits of firms that control the innovation. Rigidity of price reduction is, therefore, a fundamental element of the oligopolistic structure.

The possibility of obtaining higher profits for the oligopolistic firms, which would be greater than those obtained in competitive markets but smaller than those obtainable in a monopolistic situation, is the result of the existence of "barriers to entry" to new firms that are potential competitors, and of the trend toward concerted patterns of behaviour among the established firms. The effectiveness of the barriers to entry, which determines the actual level of profits, will depend on the specific advantages enjoyed by the already established firms. According to Bain (88) these advantages can be classified into: absolute cost advantages, which derive primarily from the control of more efficient productive technologies, from imperfections in the inputs and labour markets, and from preferential access to finance; advantages due to product differentiation, which result from established consumer preferences and are closely linked to product know-how, marketing skill, and commercialization structures; and advantages of scale in production and distribution, which derive from better organization and from horizontal and vertical integration.

In some modern concentrated industries, electronics for example, prices fall sometime after a particular product is launched on the market, and therefore the rigidity of price reduction would apparently not exist. However, the price referred to by oligopolistic theory is the sum of production costs plus "normal" profits. Any profit higher than this imputable remunerative limit is an "extra" profit resulting from speculative actions or monopolistic power. Consequently, decreasing prices would reflect the fact that higher initial prices include these "extra" profits made possible by monopolistic appropriation of technology, and that they drop to the level of "normal" profits when the firm launches a better product, when the enterprise feels that there is sufficient market to expand profits, no longer through "extra" profits per product sold but rather by an increase in total profits through a higher volume of sales, or - finally - when other firms have entered the market with similar products.

Oligopoly theory distinguishes between two main types of oligopolistic situations: concentrated and differentiated oligopoly. In concentrated oligopolies there is a greater degree of concentration and firms produce relatively homogenous products, with a few firms controlling all or most of production. The technological advantages of production processes play a most important role in this case. In differentiated oligopolies there are numerous firms and each carves a "market niche" for itself by introducing variations in a product line that differentiate its own product from those of the competitors, and by stressing these real or apparent differences through advertising and marketing techniques. Consumer preferences play an important role and thus a new type of "barrier to entry" would appear: the level of investment in product sales (marketing, advertising, distribution, etc.) required to obtain an adequate clientele (89).

The predominance of oligopolies is also linked to the worldwide expansion of manufacturing industry. Sylos Labini summarizes the situation as follows:

"In brief, modern capitalism is characterized in many important branches by a process of expansion in the size of a relatively decreasing number of firms; the main conditioning factor of such a process is technical progress. Such a process, helped by that particular progress taking place in the means of transportation, has surpassed national boundaries to embrace first whole countries and, in certain branches, a good part of the world" (90).

Oligopolies are considered inevitable in developing countries because of the limited size of their markets and the relatively large scale of output required for

efficient production with modern technology. Thus Merhav (91) argues that "underdeveloped countries depend for their growth on the techniques of advanced countries, and the consequences of the scale of output determined in the latter on the competitive structure of the former result are immediately obvious: Their limited markets cannot support but a few firms in each branch of production." Therefore, the main findings of oligopoly theory are seen to apply to developing countries, although several important modifications have been introduced to take into account their condition of dependence, and in particular the fact that the spread of multinational corporations and the dependence on foreign technology significantly alter the nature of these "peripheral oligopolies."

For example, Sylos Labini points out the accentuated social implications of the rise of oligopolies and of technical progress for the developing countries:

"...'The oligopolistic mechanism' of the distribution of the fruits of technical progress (increase in money incomes rather than price reduction) and the different kinds of scale economies give rise to 'privileged firms' and to 'privileged industries,' where the privileges concern both capitalists and workers. In backward countries the said mechanism gives rise to privileged 'social enclaves' which need political protection and have important political implications" (92).

Sercovich (93) has shown the various ways in which the technological advantages associated with the barriers to entry imposed by the leading oligopolistic firms are exploited in the peripheral countries. These firms recreate the oligopolistic structures prevailing in their original markets through the establishment of subsidiaries and the granting of licenses to local manufacturers. Tavares (94) has introduced the concept of "competitive oligopoly" to describe new forms of competitive behaviour found in Brazilian industry that departed significantly from the form of competition prevailing in concentrated and differentiated oligopolies.

Another line of thought in oligopoly theory postulates that product differentiation - a characteristic of differentiated oligopoly - frequently imposes the need for different technologies, and that there are few techniques actually available for the production of a given commodity at a particular scale of output. Thus Merhav (95) and Sylos Labini (96) both emphasize the importance of the selection of the commodities to be produced, rather than the problem associated with the choice of techniques, considering that the latter is largely a by-product of the former. This leads Sylos Labini to propose:

"If the problem of the choice of techniques is largely conditioned by that of the choice of the kind of commodities to be produced and their scale of production, then it is wrong for an underdeveloped country to adopt a policy of economic growth which gives priority by means of incentives of various kinds designed to influence the decision of the managers, to the problem of the choice of techniques....it is necessary first of all to choose the kind of commodities the production of which is to be promoted and only subordinately to decide the type of incentives to be introduced to stimulate the adoption of more or less labour-intensive techniques when this choice is really possible" (97).

A recent article by Fajnzylber (98) introduces some additional modifications to oligopoly theory to make it more relevant to the situation of Latin American countries. Based on an extensive empirical survey of the operation of multinational enterprises in the Mexican economy, he points out that in many cases there appears to be a wide range of technical options with regard to the scale of production, adding also that there is the economic possibility of using part of the installed capacity without affecting the competitive position of the firm in the internal market. This last argument is also applicable to oligopolies in the central countries (an unused capacity reserve is seen as one of the mechanisms for keeping potential new competitors out of the market), but it acquires special dimensions in the small and excessively protected markets of the less developed countries.

But Fajnzylber's main criticism refers to the notion of "barriers to entry." He points out that the factors that constitute the oligopolistic barriers to entry do not exist for the subsidiaries of multinational corporations that try to penetrate established industrial markets in the Latin American economies. These corporations have already surmounted the barriers to entry in their own original and more competitive markets, and the investment required to operate in the peripheral countries represents a marginal sum in comparison with the total financial resources at their disposal. Therefore the newcoming subsidiaries can confront, possibly during a long period of time,

an eventual price and advertising war waged by the subsidiaries already established. This would make the established firms incapable of stopping the incorporation of new firms, leading to the paradox that in the small peripheral markets it is possible to find a larger number of firms operating than in the original markets of the multinational corporations. This situation would be found primarily in differentiated oligopolies.

On the other hand, these "barriers to entry" become an impenetrable wall when the aspiring entrants are local private enterprises (state enterprises can surmount these barriers due to administrative government decisions to reserve markets in exclusivity, establish joint ventures, etc.). Lack of financial, marketing, administrative, and technical capabilities would make it almost impossible for a local firm on its own to enter a new market where subsidiaries of multinational corporations dominate unless some form of alliance (e.g., through licensing agreements) is forged with another multinational.

The implications of the transfer of oligopolistic market structures for income distribution, concentration and denationalization of production, employment, and allocation of resources are also examined by Fajnzylber, who points out that this replication of oligopolistic structures does not have any positive effect on technical progress in the peripheral countries:

"...oligopolistic structures are effectively transferred to the recipient countries, although at an inferior level of efficiency, the high rates of profitability are also reproduced locally, but what does not appear is the process of technological innovation generated locally. This omission does not prevent that part of the profits generated locally be allocated to pay for the expenditures on technological innovation activities made in the country of origin.

"In short, while in their country of origin the leading enterprises in oligopolistic structures generate the process of technological innovation, in Latin America the leading enterprises in local oligopolistic structures, subsidiaries of the first, utilize and with that amortize the expenditures in research made a few years before in the respective country of origin" (99).

TECHNOLOGY AND CAPITAL ACCUMULATION AT THE INTERNATIONAL LEVEL

Starting with the Marxist critique of capitalist production and the place of technology in it, a theoretical body has been developed that links the process of capital accumulation and its international expansion with the nature and impact of technical progress.

Because the roots of this school of thought are found in the writings of Marx, it is interesting to summarize briefly some of Marx's own conceptions of the relations between technology and economic growth.

Marx and Technology

Marx considered that technological and economic processes are closely interwoven and that they affect each other in many ways. According to Rosenberg, "rather than positing some unidirectional chain of causation for technological change, Marx offers a far richer mode of analysis, one which emphasizes the mutual interactions and feedbacks between economy and technology" (100); thus Marx rejected both the extreme view of technological determinism and that of economic factors linearly determining the course of events in technical progress.

For Marx, technology is at the centre of those activities that are distinctly human. "The simple elements of the labour process are 1) purposeful activity, that is work itself, 2) the object on which the work is performed, and 3) the instruments of that work" (101). Thus, if technology is considered as human knowledge put at the service of production (or the labour process), it appears in the instruments for work, in the "purposeful activity," which presupposes an initial conception and design of the work to be realized, and also in the object of work, which would incorporate human knowledge as a result. In a broader sense, Marx considers that technology is what mediates between man and his relationship with the external material world.

The transition from artisan work to manufacturing and then to large-scale modern industry, with the associated changes in the way the labour process is organized under capitalism, was one of the key issues on which Marx focused with regard to

technology. Manufacturing was considered as an extension of handicraft, where instead of one artisan performing a whole range of operations in the production of a single commodity, the process was broken into a series of discrete steps each of which was assigned to a different worker. Nevertheless, this growing specialization - which had many consequences that were the subject of Marx's careful attention - shared a common feature with the medieval handicraft system: a continued reliance upon human skills and capacities.

Large-scale modern industry represented a radical break in the history of capitalism. For the first time production did not have to rely on human skills as applied directly to the productive process, but rather was mediated by machines in the sense that large-scale industry took over the production of machines, which were then used in the production of other commodities. This allowed the fusion of modern scientific and technical knowledge - which was incorporated into the production of machines - with productive activities, which now could be carried out at a greater speed, with greater accuracy, mobilizing nature's forces, and with the worker playing the role of a controller or supervisor rather than a direct intervener in the process itself (102). According to Rosenberg:

"The decisive step was the development of a machine technology which was not heavily dependent upon human skills or volitions, where the production process was broken down into a series of separately analyzable steps. The historic importance of Modern Industry was that it incorporated these separate steps into machine processes to which scientific knowledge and principles could now be routinely applied... when this stage has been reached, Marx argues, technology becomes, for the first time, capable of indefinite improvement" (103).

The trends toward international expansion and large-scale production, which characterize contemporary "big industry," were clearly anticipated by Marx. Improvements in transportation and communications were seen to follow the advent of modern large-scale industry: "...the means of communication handed down from the period of manufacture soon became unbearable fetters on large-scale industry, given the feverish velocity with which it produces, its enormous extent, its constant flinging of capital and labour from one sphere of production into another and its newly created connections with the world market. Hence...the means of communication and transport gradually adapted themselves to the mode of production of large-scale industry" (104). Innovations in this field were also forms of reducing the time of circulation of capital. Large-scale production led to the possibilities of exploiting economies of scale, of introducing measures to utilize by-products, and of introducing capital-saving innovations, particularly when technological change reaches the machine-producing sector. All of these considerations led Marx to attach great importance to the capital goods sector of modern industry.

Finally, Marx viewed the evolution and interaction of technology and production in a dynamic way:

"Modern industry never views or treats the existing form of a production process as the definitive one. Its technical base is therefore revolutionary, whereas all earlier modes of production were essentially conservative. By means of machinery, chemical processes and other methods, it is continually transforming not only the technical basis of production but also the functions of the worker and the social combinations of the labour process" (105).

Technology and Capitalist Production

In this school of thought capitalist production implies the generalized production of commodities. The organization of economic and social life is so imbued with capitalist production views that relationships among men become hidden and metamorphosed as if they were relationships among things (commodities). The value of a commodity (both exchange value and use value) depends on the way men have organized to produce it, and therefore it incorporates a historically specific social relationship and a mode of production.

As human knowledge applied to capitalist production, technology acquires the nature of a commodity. Technology becomes impregnated with the social relationships implied in capitalism, and its development is determined by these relationships.

Capitalist production is also the production of surplus value. Surplus value

is the expression of a social organization of production which, on the one hand, has the owners of the means of production (capitalists) who decide what, how, and for whom to produce, and, on the other, has those who have only their work to sell (workers). Surplus value arises because the capitalist does not compensate the worker for all the time he has dedicated to his work, but pays only a part equivalent to that fraction of working time necessary to reproduce the work force. The rest of the time the worker is producing surplus value to the benefit of the capitalist. This surplus value allows the capitalist to increase the amount of money that he initially invested in production and, through this accumulation, allows him to reproduce his condition of owner of the means of production and the material conditions for the production that operates to his benefit. This accumulated surplus value is transformed into capital. Thus, the social capital/labour relationship defines the capitalist mode of production, and its antagonistic nature supports and determines the contradictory development of the system.

The need to accumulate surplus value and capital leads the capitalist to speed up the concentration of workers and means of production (the latter to a progressively higher proportion than the former) under his power for purposes of reducing his production costs and hence increasing his profits. Capitalist production thus carries with it the concentration and centralization of capital, that is, larger volumes of capital that require broader markets for their realization. This arises in conjunction with the emergence of large-scale modern industry.

Consequently, capitalist production is also the reproduction of capital as a social relationship. To this end, the capitalist must unceasingly accumulate surplus value. Since a working day has physical and psychological limits, the method used to increase surplus value consists of decreasing the working time socially necessary for the reproduction of the work force. Since the capitalist cannot reduce the monetary remuneration as he wishes, the route he usually follows is to introduce social and technical changes that increase the productivity of labour, so that labour will produce more in less time and thus reduce the value of the labour incorporated into the commodities, as well as the cost of materials and of the means of production. Thus technical progress is one way in which the capitalist may increase the surplus value under his control; this allows him to reduce the value of the labour force and thus to counter the essential antagonism that sets him in opposition to the worker.

Marx pointed out the absolute contradiction between the revolutionary technical basis of modern large-scale industry and the form it takes under capitalism, with the capitalist extracting the surplus value from the workers:

"...large scale industry, by its very nature, necessitates variation of labour, fluidity of functions, and mobility of the worker in all directions. But...in its capitalist form it reproduces the old division of labour with its ossified particularities...This absolute contradiction does away with all repose, all fixity and all security as far as the worker's life situation is concerned; how it constantly threatens, by taking away the instruments of labour, to snatch from his hands the means of subsistence, and, by supressing his specialized function, to make him superfluous" (106).

The processes of concentration of the means of production and centralization of capitals (107) imply the development of productive forces and the progressive socialization of labour and the means of production. This is the historical role played by capitalism and is at the root of its contradictory nature: the socialization of production becomes increasingly in conflict with the private appropriation of the means of production and the extraction of surplus value. This central contradiction of capitalism, viewed from the perspective of technology, can be expressed in the following terms: the process of capital accumulation and the drive for profits both accelerate technological development and at the same time hinder it. On the one hand, technical progress - which in the context of capitalism tends to reduce the value of labour incorporated into production - supports the process of accumulation by augmenting labour productivity through the application of science to technology and then to production. On the other hand, technical progress hinders the process of capital accumulation for it constantly increases that part of capital that is required for the means of production (fixed assets) in relation to that which is required to employ the means of production (labour) (108). Therefore, as a result of technical progress, larger amounts of capital will increasingly be required to maintain a constant rate of profits, and the capitalist will be forced to allocate an ever-increasing proportion of his profits to investment in the means of production.

In most cases technical progress under capitalism implies a decrease in the use of the labour force and an increase in the use of machinery, equipment, and materials (e.g., mechanization, automation). Therefore, the result of this type of technical progress is an increase in the organic and technical composition of capital. The ratio of surplus value to variable capital would also increase for the same reason, but a limit would arise because the capitalist cannot reduce real wages at his discretion,especially in societies where salaries are relatively high and trade unions well organized, and because he cannot raise prices indefinitely due to competition, or if he is in a monopolistic situation, due to demand elasticities. Consequently, there is a trend for the organic composition of capital to increase to a larger extent than the ratio of surplus value to variable capital, producing a decline in the profit rate as a result.

The efforts to resolve these two contradictory tendencies lie at the heart of the relation between technical progress and the process of capitalist accumulation. The declining trend of the profit rate in the long run is the result of opposing forces that are permanently struggling against each other. Capitalists, in their quest to increase profits, unleash a complex of forces and mechanisms that result in a general decline in the profit rate (109).

One of the ways of suppressing this contradiction without changing the basic exploitative nature of capitalism has been to slow down the rate of technical progress, limiting the introduction of innovations that would reduce drastically the value of labour incorporated into production. The gradual shift of more advanced techniques from industrialized to nonindustrialized countries - with lower wage rates - is seen as a way of achieving this, as is the promotion of labour-intensive techniques (110). Finally, the expansion of the capitalist system to other areas where it has not yet been fully extended is also seen as a way of halting temporarily the inexorable trend of declining profit rates under capitalism.

The efforts to fight against this decline require an increased concentration of the means of production, leading to ever-larger scales of production, and an increased centralization of capitals, so that they can be allocated more "efficiently" to stave off the declining trend of profit rates. Thus a transition from competitive to monopolistic capitalism emerges, and this took place in the last decades of the 19th century and the early decades of the 20th century (111).

Imperialism and International Economics: The Market Question

The expansion of capitalism at an international level through commercial, financial, and technological networks must be understood as arising out of its main contradictions. The configuration of an international economy dominated by the capitalist mode of production is the result of the processes of capital concentration and centralization - which imply the internationalization of productive structures and the establishment of oligopolistic and monopolistic markets at the international level - and of the attempts of capitalists to overcome the tendency for the rate of profits to decline.

Since their origin as capitalist economies, Western industrialized countries have faced the problem of realization of the surplus generated by the industrial sector. In these economies, even though agriculture served as a support for industrialization, the relative scarcity of agricultural surplus made it impossible to create an internal market sufficiently large to absorb and utilize the whole industrial surplus in the early stages of the development of capitalism.

Exporting part of the surplus was then a way of speeding up the growth of the industrial sector in these economies. In fact, the existence of foreign markets was an incentive to increase the productivity of industrial labour and with it, national income and production. As capital accumulation and industrialization progressed in the central countries, it became necessary to increase imports of agricultural commodities and raw materials from the periphery, which, involving much lower production costs, made it possible to cheapen (relatively) the labour force and to depress the value of the elements of constant capital in central countries, and thus to counter the decline in profit rates and support accumulation.

Thus the development of capitalism posed from the beginning the problem of unequal development between agriculture and industry and hence of countries specializing in one or the other of these types of products. Concurrently, the international expansion of capitalism, and specifically the role of exports and imports, was prompted by the need to realize surplus, reducing the costs and supporting profit rates.

The existence of foreign markets made it possible for capital to move toward regions where profit rates were higher.

Thus an international division of labour was established between countries exporting mainly primary goods and countries mainly producing manufactured goods. This division of labour maintained and increased the subordination of the first to the second group of countries, leading to the exploitation of the developing countries for the benefit of the dominating nations (either directly, by lowering the value of the constant and variable elements that make up the profit rate of the central countries, or indirectly, by generating very high profit rates in the periphery, which consequently increased the centre's average profit rate). The peripheral countries' role as consumer of the surplus generated was not significant because of the narrowness of their domestic markets. Their basic role was to support the industrialization of the central countries.

When capital concentration and centralization lead to an accumulation of surplus in the centre to such an extent that part of it can no longer be reinvested in the centre for it would further depress the profit rate, then the transfer of some industrial activities to the periphery starts as a gradual systematic process going beyond the simple establishment of exporting enclaves to exploit natural resources. Capitals are extensively exported in the form of money and products and the peripheral industrial and financial sectors flourish. This process was particularly sharpened after World War II, when the world monetary system opened a large expansionary wave that lasted until 1971.

The surplus generation-realization contradiction, which reflects the contradictory phenomena of capitalist production, is internal to the capitalist mode of production (112). The concrete way capitalists attempt to resolve this contradiction determines, in each specific and temporary situation, the size and dimensions of the market served by the capitalist mode of production, whose expansion tends to capture or destruct precapitalist modes of production, as well as to reallocate productive factors and resources to industry, to the detriment of the rural areas.

The profit motive, and capital concentration and centralization (and hence the monopolistic control of technological innovation), translate into a trend toward imbalanced and disproportionate growth among the different productive sectors of capitalist activity. This complicates the problem of surplus realization and encourages the search for solutions beyond the confines where the capitalist mode is already fully operative (113). According to the specializations imposed by the international division of labour, and according to the type of technological progress that supports each productive activity, it would be possible to infer whether this disproportionate sectoral growth will ratify or modify the degree of regional, national, or international unequal development. Internationalization of certain productive activities is, at the same time, a way of balancing the negative effects that this sectoral lack of proportion has on the profit rate, as well as a way of reproducing it in the periphery.

Science and technology are now becoming increasingly important for the accelerated generation of surplus and for its disposal. It has been pointed out that "the international centres which produce modern technology present themselves, in relation to the control of capitals, as 'vortices' which subordinate large masses of capitals previously dispersed in their autonomy" (114). The oil-producing countries, which by themselves are unable to employ the large sums of money they have been able to extract since the rise in oil prices, are an example of this.

Summarizing: science and technology, which were used intensively to support production since the beginnings of capitalism - when handicraft production was transformed into manufacturing and later into modern large-scale industry - also helped in expanding the sphere of capital circulation and in defending profits in opposition to the rise in wages, thus providing a basis for capitalist accumulation. In the imperialistic stage, science and technology are further transformed into means for the extraction of surplus and its transfer from the dominated to the imperialistic countries. As such, technology greatly accelerates the rate of capital accumulation and for the same reason renews constantly, and at higher levels, the problems of absorption and utilization of the surplus, thus reinforcing the overall tendency for profit rates to decline.

VIEWS ON TECHNICAL CHANGE AT THE FIRM LEVEL

Most studies of technical change at the firm level, both theoretical and empirical, use the general framework of neoclassical theory and have been carried out in

the Western industrialized countries. In their survey of the literature Kennedy and Thirlwall (115) identify two approaches to the study of technical progress: the first focuses on the economic effects of changes in technology, primarily at the aggregate level, and the second focuses on technical change itself and its conditioning factors. The preceding review of schools of thought on technology, development, and industrialization covered some of the issues raised by economists who follow the first approach; therefore the following sections will deal briefly with technical change at the firm level and its determinants.

According to standard economic theory, the sequence of activities involved in the process of technical change starts with the performance of research and development (R&D), leading to invention and then to innovation. The studies of research and development activities in industry examine the growth of expenditures, the rates of return to investment in R&D, the nature of R&D tasks, the impact of R&D in the generation of new knowledge, and the determinants of R&D performance. Particular attention has been given to the relation between the size of firms and the amount of R&D activity, although findings are not conclusive with regard to whether increases in firm size lead to proportionate increases in R&D activities. The same can be said about the relationship between the amount of research and industrial concentration (116).

With regard to the problem of invention, which is defined as "the devising of new ways of attaining given ends," it is possible to identify three schools of thought (117). The first adheres to the "heroic" theory of inventions, which gives preeminence to the individual genius and his intuition and foresight; the second espouses the "cumulative synthesis" point of view, according to which basic inventions arise inevitably as a result of the accumulation and integration of minor changes and inventions; and the third postulates a "mechanistic" view, which stresses that invention arises as a response to concrete needs, particularly of an economic nature ("necessity is the mother of invention"). Evidence shows that the heroic mode of invention is becoming less and less frequent in today's industrial world, where organized research plays a dominant role in invention. Evidence is less conclusive regarding the other two schools of thought.

The process of innovation, which is defined as the commercial application of inventions for the first time, has been more widely studied and will be examined below in more detail.

The diffusion of innovations has received substantial attention in the literature on the economics of technical change. A recent study summarizes earlier findings and presents the results attained in an international research project involving six Western European countries and covering ten processes (118). The study attempted to assess the scope and extent of diffusion of the chosen processes, identify the factors that speed up their diffusion, and account for the differences encountered between countries. However, these studies focused primarily on the technical nature of the innovation and on the characteristics of the enterprises whose individual decisions to choose the technique under study, at different points in time, gave rise to the phenomenon of diffusion. By and large these studies left out the structural characteristics (at the national and international levels) of the industrial branch where the innovation took place. Studies carried out in Brazil addressed these issues and tried first to examine the characteristics of the industrial structure and to relate the findings on diffusion of innovations to it. This required a selective return to some Schumpeterian concepts of innovation, which treat technological change as an instrument of capitalist competition (119).

However, Rosenberg has recently criticized the traditional approach, which distinguishes sharply between the processes of invention, innovation, and diffusion. In his view, these distinctions - which are a legacy from Schumpeter's conceptualization of innovation - have distracted attention from the gradual and minor changes that take place in technology at the plant level, which although less dramatic than the major innovations that have received preferential attention by economists, are nevertheless a most important source of technological improvements. Rosenberg concludes:

"...our dominant conceptualization of innovation has, in many basic respects, served to obscure rather than to illuminate the process of technological innovation. It has done this by creating artificial conceptual disjunctions between innovative activity and other activities with which it is not only linked, but which in fact constitute major parts of the historical process of innovation itself. It has done this

primarily by employing concepts which do not explicitly recognize the role of patterns of events at the technological level. As a result, 1) we confine our thinking about innovations to features and characteristics which are likely to be true only of major innovations, 2) we focus disproportionately upon discontinuities and neglect continuities in the innovative process, 3) we attach excessive importance to the role of scientific knowledge and insufficient importance to engineering and other 'lower' forms of knowledge, and 4) we attach excessive significance to early stages in the process of invention and neglect the crucial later stages" (120).

The Process of Innovation and its Determinants

The process of innovation at the enterprise level and the factors that influence it have received greater attention during the last fifteen years after a relatively long period of neglect (Schumpeter in the late 1920's was the last to treat these issues in detail in economic theory until the present wave of studies began in the late 1950's).

In spite of substantial results from empirical research (121), the evidence in favour of most propositions on technological innovation remains inconclusive, and much more research will be required before anything definitive can be said about the process of technological innovation and its determinants. Nevertheless, some hypotheses and postulates appear more plausible than others in view of their logical construction and the relative amount of evidence supporting them.

Pavitt summarizes the situation with regard to factors influencing the success of innovation as follows:

"No universal recipe can be written which will increase the chances of successful innovation in all firms, in all industries, of all sizes and at all times. Nevertheless, one can at least identify the factors that are likely to influence the firm's activities in relation to industrial innovation. One of these factors is internal to the firm, namely its strategy towards industrial innovation. Other factors are external to the firm: first, the nature and scope of opportunities open to the firm for enhancing its technology as part of its search for profits and efficiency; second, the size of the firm; third, the nature and degree of market competition that the firm is facing; and fourth, the general economic environment in which the firm is working, especially insofar as this environment influences the resources, incentives and rewards for innovative activities" (122).

Freeman (123) has proposed a classification of innovation strategies for a firm that takes into consideration issues such as the firm's performance of fundamental research, applied research, experimental development, design engineering, technical services, scientific and technical information, and so on.

The "offensive" strategy is designed to achieve technical and market leadership by being ahead of competitors in the introduction of new products and processes, which requires strong in-house activities in science and technology. The "defensive" strategy aims at not being left behind by competitors rather than at being first in the world, and still requires a substantial in-house scientific and technological effort. The "imitative" strategy involves the deliberate imitation of innovations developed elsewhere, often through the purchase of licenses and know-how from an "offensive" or "defensive" innovator. The "dependent" strategy involves the acceptance of an essentially subordinate role in relation to other stronger firms. The "traditional" strategy involves little or no innovation in products and processes, because the market does not demand innovation or competition does not compel it. Finally, the "opportunist" strategy involves identifying and exploiting a niche not requiring in-house scientific and technical capabilities.

The adoption of a particular strategy, or mix of strategies in large diversified firms, has important implications for the performance of scientific and technological activities within the firm. Problems such as the minimum critical size for R&D efforts arise, for there is evidence that a particular level of investment is required by an innovating firm before it reaches a threshold beyond which it is able to exploit scientific advances. Townsed (124) considered that British firms required a minimum of £20,000 per researcher in 1973 and that at least five researchers would be required to form a viable team. Considering that 2% of sales would be an adequate figure to spend on research, he concluded that only firms with more than £5 million would be able to engage actively in research and development at the minimum level (which may only

guarantee capabilities for an imitative strategy).

Regarding factors external to the firm, the opportunities to enhance technology through devising and introducing new products and processes will vary considerably from industry to industry, depending on the characteristics of the technology itself, on market receptivity, and on the extent to which suppliers of machinery, materials, and components are engaged actively in innovation. Thus the first three strategies (offensive, defensive, imitative) are identified with research-intensive industries, where technological change plays a very important role in competition, whereas the traditional and dependent strategies are associated with industries in which technological change does not play a major role. Not only the opportunities but also the ways in which technological capabilities can be enhanced will vary according to the particular branch of industry being considered. Depending on the nature of the technology involved, improvements may be effected through licensing agreements, investments in fixed assets, changes in product design, and so forth (125).

The nature of competition has a direct and considerable influence on the pressures for industrial firms to innovate, as well as on the types of innovations that are introduced and the rewards they bring. The structure of the market in which the firm operates, particularly the degree of industrial concentration and monopoly power, has been considered by some economists as one of the main determinants of innovative behaviour. This is closely associated with the arguments concerning the relationship between size of firm and innovation. On the one hand, it is argued that since innovations are costly and risky, a high degree of monopoly (closely associated with large enterprises) is essential for innovation, since this creates the organizational slack and provides the financial resources, the minimum threshold, and the degree of market certainty that are required for innovations to be successful. On the other hand, it is argued that concentration and monopoly power decrease the incentives to innovate, generate a rigid, risk-averting attitude, and stifle inventiveness under a bureaucratic shell, primarily because it is possible to maintain high profits without innovating.

In their review of the literature Kennedy and Thirlwall conclude:

"The evidence appears to be heavily weighted against the hypothesis that a necessary condition for technological change and progressiveness is that firms should be large scale and dominate the market in which they operate. From the very origins of technical change, in the work that is put into research, to the commercial application of new knowledge, it does not appear that large firms or monopolistic industries are necessarily more dynamic or progressive, or produce more fundamental technical advance. After a certain threshold size there is even evidence that R&D activity and the number of patents issued appear to increase less than proportionately with size. Moreover, there is some evidence that it is not always the largest firms that innovate the quickest despite their presumably more favourable access to resources. Large firms by no means have a monopoly on fundamental changes either. Major technological breakthroughs come from a variety of sources" (126).

The general economic environment also influences innovative activities, particularly through the structure of rewards to innovating firms. For example, in periods of economic decline or stagnation, research and development expenditures are usually among the first to be cut.

However, it may also be the case that an unfavourable environment may force some changes in organization and attitudes within the firm, leading to technical changes and innovation as a way of improving performance. Considering other economic factors, the prevalence of relatively high interest and inflation rates would bias the firm in favour of short-term and safe R&D projects that can produce quick returns on investment, leaving aside the longer-term, more risky, and potentially more rewarding ones. Taxation, incentives, subsidies, and other government intervention measures (policy instruments) would also have an important impact, although they have not been studied in sufficient detail to provide any conclusive evidence (127).

Endogenous Views on Technical Change

A series of both empirical and theoretical efforts have been made during the last fifteen years toward the development of an "endogenous" view of technical change (128). These efforts grew following realization of the difficulties involved in explaining technical change in terms of traditional economic theory. Complaints in this respect focused upon two major aspects: (a) the relevance of inducement mechanisms

concerning factor-saving bias, and (b) the assimilation of technical change with shifts in the production function (129).

Salter, among others, questioned Hicks's assertion according to which "a change in the relative prices of factors of production is itself a spur to invention, and to invention of a particular kind - directed to economizing the use of a factor which has become relatively expensive" (130). Salter cogently argued that under competitive conditions, the individual firm is simply not interested in the particular factor-saving bias of technical improvement (131).

The assimilation of technical change to shifts in the production function has also been subject to strong criticisms. The assumptions of continuous isoquants over the whole range of production possibilities and of readily available alternative techniques at zero costs were also considered highly artificial. Insofar as eligible techniques under varied economic conditions imply an expensive and uncertain search process, the distinction between movements along the production possibilities frontier and shifts in such a frontier may be inadequate. Later developments along neoclassical lines, i.e., the concept of the innovative possibilities frontier or that of a "fundamental production function," did little to improve the explanatory value of received theory, since the basic assumptions remained unaltered (132).

Hence, efforts toward the explanation of technical change adopted new directions, giving rise to new concepts and avenues for research. These proved to be useful in the treatment of other aspects - previously separated from technological factors - such as (a) accounting for the timing of innovations; (b) finding linkages between specific innovations and the resulting growth in resource productivity; and (c) accounting for both the rate and the direction of diffusion of innovations throughout the economy.

The following main features of these new avenues of thought can be singled out: a departure from the Schumpeterian concept of innovation with its emphasis on "major" technical changes; a distinction between the introductory stage of an innovation and the subsequent stage of diffusion involving modifications and improvements to the original innovation; the development of concepts regarding the process of technological learning; the introduction of the idea of localized innovation; and, more generally, the adoption of a "heuristic" approach to innovation.

Against an intellectual background biased toward innovations involving breakthroughs based on scientific knowledge that purports to be of the widest degree of generality, a number of empirical studies have shown conclusively the importance of minor innovations (133). These involve any nontrivial change in processes and products and consist of "mere" technological or engineering knowledge of a specific and particular nature.

Whereas the introductory stage of an innovation (first usage at the commercial level) involves cost reductions with regard to previous "best-practice" techniques, subsequent enhancements - largely through nonroutine intramural engineering efforts, but also by engineering design firms - often involve relatively more important steps in the cost-reducing direction. In fact, the diffusion process is not looked upon as a mere adoption of an innovation by an increasing number of firms but as a cumulative process of improvement and adaptation belonging to the postintroductory phase of an innovation. Thus, the inventive activity is described as a gradual process of accretion where in general continuities are much more important than discontinuities.

In this way, the postintroductory stage of technology enhancement is seen not as closing the invention stage but as inaugurating a learning period. This period has been researched by resorting to technological "learning by doing" and "learning by spending" models. Even though these approaches may be thought to be not yet fully developed and have received some criticisms (134), they seem to open promising research perspectives and have already borne considerable fruits at both theoretical and empirical levels.

The main output resulting from incremental technological learning, both at the plant and at the engineering design firm levels, is minor innovations sharing the nature of localized technical change. When firms undertake innovational activities, they usually have their own "technological frontier," which is strongly influenced by the initial design conditions of the technology they currently use (thus emphasizing the "putty-clay" character of technical knowledge). They do not explore along the whole production possibilities surface but only examine those points more directly relevant to

them, thereby generating "localized" innovations which affect only a particular process. These innovations are highly appropriable and involve changes in the shape of the production surface rather than shifts in it. At the same time certain "compulsive sequences" at the microeconomic level are involved, and firms will orient their search in the direction of the most compelling and obvious solutions to their technical adaptation problems. This orientation may be insensitive to a considerable range of changes in the values of macroeconomic variables. The consideration of these circumstances leads to the formulation of a microeconomic approach to technical change in terms of a "bottleneck analysis," which overcomes the customary disregard concerning day-to-day problems posed by the existing technology.

Technical Change and Innovation in Less Developed Countries

Relatively little work has been done on the nature of, and the factors influencing, technical change at the firm level in the less developed countries. Among the few studies that can be identified, Katz (135) has examined the impact of scientific and technical activities on the rates of growth in Argentinian industry, finding that the learning process involved in actual production, and the technological activities not properly belonging to the field of "research and development" (adaptation of techniques, plant improvement, repair and maintenance, quality control, etc.), have an important influence on the growth of productivity. Several Indian studies have also covered some aspects of the process of innovation at the firm level, such as the performance of research and development and the impact of innovations on industrial growth (136). Another group of studies has examined managerial attitudes toward innovations (137), while others focus on products, characteristics, and the nature of the process (138).

However, almost without exception, the studies of technological innovation in less developed countries that attempt to go beyond descriptive analysis borrow and adapt concepts and theories put forward in developed countries. Economic studies of innovation and its effects on rates of growth use the instruments of the neoclassical school, while the studies of entrepreneurial attitudes toward innovation are generally based on the conceptual framework of the functionalist school in sociology.

Among the studies focusing on the determinants of technical change in the less developed countries is one carried out in Sao Paulo by a joint Brazilian-American team. The conceptual framework borrows from a model of the innovation process proposed by Utterback and Abernathy for the North American context (139). This model attempts to show that as a product matures, the mode of innovation shifts from radical product innovation, which is performance maximizing, to incremental innovation, which is cost minimizing, and process innovation increases in relative importance to product innovation. The model proposed by Utterback and Abernathy focuses on the dynamic evolution of the firm, following it from a fluid state, associated with the initial stages of product design where radical modifications may be introduced in the innovation, to the specific state, where the product is standardized and stable and the process of production more rigid, efficient, and based on economies of scale. A transition state is said to occur when the base for competition shifts from performance to cost.

The model predicts that firms that are at different positions in the evolution of their product and process technology will respond to different stimuli, undertake different types of innovation, and thus confront different barriers to innovation. Following this rationale and using hypotheses derived from the model, the empirical phase of the study consisted of interviews with more than one hundred firms in the Sao Paulo area to examine their possible response to various mechanisms that would induce innovations (140).

The problem with studies of technological innovation that borrow conceptual frameworks lies precisely in their adoption of models conceived for other situations. This adoption would imply ignoring the substantial contextual differences that exist for technical change and innovation. Acknowledging the heterogeneity of levels of industrialization in the developing world, some common characteristics will be highlighted to emphasize the difficulties in applying models conceived for other situations.

First, the process of industrialization takes place in the general context of a dependent relationship with the countries that supply technological knowledge. The overwhelming majority of industrial innovations are not indigenous to the developing countries. They originate in the Western industrialized market economies and then are

transferred over a period usually extending from ten to twenty years. Therefore, models developed to explain and predict innovative behaviour indigenous to a firm, branch of industry, or country have little relevance to the situation in developing countries.

Second, the size and characteristics of the markets in less developed countries differ widely from those in countries where innovations originate. The smallness of markets, the high degree of concentration of production, the predominance of foreign subsidiaries, the segmentation of markets, and the different types of firms participating in these markets (foreign, local, private, joint ventures, state) all combine to make most postulates and theories about technical change at the firm level irrelevant, particularly when they emphasize the proximity to markets and to suppliers of equipment and machinery as conditions for successful innovation. The markets of developing countries are not the original markets for which innovations are introduced, and their capital goods industry is (with the exception of the large semi-industrialized countries) usually incapable of providing the machinery and equipment required for tooling-up.

Third, the structure and articulation of the industrial system needs to be taken into consideration explicitly. Studies on technical innovation in the developed countries take for granted the fact that the industrial system is well-organized and operates smoothly. However, the situation in most developing countries hardly corresponds to that of a well-integrated industrial structure where innovations in one branch - particularly capital goods, basic materials, and intermediate products - feed into other branches, creating a cumulative effect that helps other innovations to take place and diffuse. In consequence, it is not enough to pay attention to the characteristics of the innovating firm alone, and considerations regarding the way in which the firm and the branch to which it belongs are articulated with the rest of the industrial sector and the economy acquire paramount importance.

Fourth, the characteristics of the firms themselves need to be considered in a different light. Most leading industrial firms in developing countries do not "evolve" from small to medium and then to large enterprises. They start large, often with excess capacity, usually as a result of foreign investment or some form of state intervention. Small local firms usually remain small in a subordinate position and seldom have the opportunity to grow, evolve, and challenge the leading enterprises in their respective branches. When the state intervenes directly as an entrepreneur, it concentrates mostly on large basic industries, where the scale of investment required is too large for local entrepreneurs and where foreign firms do not show interest. Because of scarcity of resources and government prestige, a general attitude of risk aversion not conducive to innovation is adopted. For all these reasons, it cannot be assumed that a general model of the innovation process will be adequate for such a variety of situations. Different types of enterprises will show different forms of rationality and this will condition their behaviour and attitudes toward technical change.

Fifth, most of the economic literature on innovations, with the exceptions noted in the preceding section, focuses on "major" innovations and neglects the small adaptations and improvements that are the main sources of technical change in the developing countries. In the late 1970's there were efforts under way, both theoretical and empirical, to explore the characteristics of those "minor" innovations and to assess their impact on the less developed economies (141), but these have required substantial modifications to existing theories and the development of new concepts.

Finally, the relatively high degree of government intervention in the conduct of economic and industrial affairs also alters the context in which firms operate in less developed countries. The incentives to innovate, the orientation of technical change, and the access to the sources of technical innovation for firms in developing countries will be influenced by government to a greater degree (even without their intending to do so) than for enterprises in developed countries. This, in turn, pushes the entrepreneurs in the direction of becoming political pressure groups, and to act beyond the strict limits of the firm becomes a necessary condition for the successful conduct of business.

All of these considerations point out that the nature of the innovative activity in the developing countries differs substantially from that in the industrialized economies, and that the concepts, theories, and models of technological innovation postulated in the latter need to be examined critically and thoroughly before they are applied to the former. At present there are no totally coherent and original theoretical formulations of technical change for firms in developing economies, and

consequently there is a lack of relevant theoretical propositions or hypotheses to test at the empirical level.

POLICY IMPLICATIONS OF THE DIFFERENT SCHOOLS OF THOUGHT

The various schools of thought on technology, development, and industrialization (and their ramifications) constitute a very rich source of policy recommendations. Many government policies, with their corresponding policy instruments, have been devised and justified as deriving from a particular school of thought whose validity, both on theoretical and empirical grounds, was accepted by those in power. Ideological issues are also closely interwoven with the process of selecting a particular viewpoint from which to derive policy prescriptions for scientific and technological development, for the choice of a perspective is not value-free.

Because of its high degree of development, conceptual elegance, and apparent ideological neutrality, the neoclassical school provides probably the most widely accepted conceptual framework for deriving policy implications with regard to science and technology. Behind the mathematical language of neoclassical economies there is a set of assumptions that are the real source of the policy recommendations. Thus, the assumption of marginal analysis, and those introduced by postulates and hypotheses such as the substitutability of factors, the divisibility of production, and the neutrality of technical change, provide the basis from which recommendations on the liberalization of international trade and the alignment of factor scarcities, among others, are based and propounded.

However, as was pointed out in the preceding sections of this module,alternative viewpoints that challenge the postulates of the neoclassical school have acquired greater importance during the last three decades. The structuralist views proposed first by the U.N. Economic Commission for Latin America, the recent suggestions that derive from the dependency school of thought, and the implications of new developments in oligopoly theory all give rise to different policy prescriptions. Furthermore, there appears to be a trend toward convergence among these three schools of thought in the sense of viewing the phenomena of development and underdevelopment in an interrelated way and of awarding technical progress a central role in economic growth and the process of underdevelopment. It is likely that during the next few years a new synthesis will emerge, both from the point of view of interpreting reality and of proposing policy measures. The calls for a new international economic order, however vague they may appear at present, are beginning to provide a common ground for defining alternative perspectives to the problems of development and underdevelopment.

All the schools of thought reviewed in this module share concern about the nature and impact of scientific and technical progress. The role of science and technology will become more and more important in the next few decades, for they will shape and condition the relations among countries. The new prominence that science and technology is acquiring has been underscored by many. For example, the negative impact of Europocentric science and the possibilities of obtaining "redemption through science" have been examined by Sachs (142); the need for a process of "technologization," which parallels that of industrialization, has been emphasized by Halty (143); the views of many authors, both from developed and developing countries, have been gathered by Rabinowitch and Rabinowitch (144); the 24th Pugwash Symposium on technology and self-reliance (145) has made it clear that the possibility of pursuing alternative development strategies is strongly conditioned by scientific and technological development; and Herrera (146) has proposed a new synthesis between modern science and traditional technology. These authors, among many others, emphasize the renewed importance of science and technology for the processes of development and underdevelopment.

The STPI project did not postulate a particular theory on the interrelations between science, technology, and industrialization. The review of schools of thought in the preceding sections showed that there are alternative perspectives from which to examine these interrelations. The relative lack of studies on technical change at the firm level in developing countries, as well as the absence of empirical work on the process of policy implementation, requires that further knowledge be generated on these issues before an adequate transition can be made from a particular theoretical and ideological standpoint to the design of policies and the establishment of policy

instruments. The research in the STPI project was an attempt to provide partial explanatory hypotheses that would begin to fill this gap and provide the basis for improved policy making and implementation and for further research efforts.

NOTES

(1) J.D. Bernal, Science in history, Cambridge, Mass., MIT Press, 1971; D. Landes, The unbound Prometheus, Cambridge, The University Press, 1969. For alternative viewpoints on the historical interrelations between technology and industrialization, see A. Musson, Science, technology and economic growth in the eighteenth century, London, Methuen, 1972, and on the role of science in society, see J. Ben David, The scientist's role in society, Prentice Hall, 1971.

(2) I. Sachs and K. Vinaver, Integration of technology in development planning: a normative view, in Science and technology for development: planning in the STPI countries, eds. F. Sagasti and A. Aráoz, Ottawa, International Development Research Centre, IDRC-133e, 1979.

(3) See R. Richta, La civilización en la encrucijada, Mexico, Siglo XXI, 1971.

(4) C. Freeman, The economics of industrial innovation, Middlesex, Penguin, 1974.

(5) See the examples quoted by S. Barrio in his paper Technological dependence? submitted to the Field Coordinator's Office of the STPI project. Barrio uses data from unpublished reports prepared at the OECD in the late 1960's.

(6) P. Gonod, Clés pour le transfert technologique, Washington, Institute de Développement Economique, World Bank, August 1974.

(7) F. Sercovich, Dependencia technológica en la industria Argentina, Desarrollo Económico, April-June 1973; Tecnología y control extranjeros en la industria Argentina, Buenos Aires, Siglo XXI, 1975; and Technological dependence/self-reliance: some general remarks, Lima, Office of the Field Coordinator, STPI Project, April 1976. Both Gonod and Sercovich apply the Marxist categories of use and exchange value to technology.

(8) This has been emphasized by Richta, op. cit., in his remarks on the potential and promises of science and technology for the socialist world.

(9) The work of Sercovich, op. cit., emphasizes the interpretation of technology as a commodity and the concept of the exchange value of technology as a determinant of its social use, particularly in less developed countries.

(10) On this subject see M. Brown, On the theory and measurement of technical change, Cambridge, The University Press, 1966.

(11) Ibid., pp. 9-28.

(12) For a review of these controversies see, among others, P. Garegnani, Heterogeneous capital, the production function and the theory of distribution, Review of Economic Studies, Vol. 37, 1970, pp. 407-436; L.L. Pasinetti, Switches of technique and the rate of return in capital theory, Economic Journal, Vol. 79, 1969, pp. 508-525; and G.C. Harcourt, Some Cambridge controversies in the theory of capital, Journal of Economic Literature, Vol. 7, 1969, pp. 369-405.

(13) The renewed interest in this subject was brought about by an article

by M. Abramowitz, Resource and output trends in the United States since 1870, American Economic Association, Papers and Proceedings, Vol. 46, May 1956, pp. 5-23, where he showed that the net increase in net product per capita was associated with the rise in something else - subsequently called the "residual" - than inputs of the physical capital stock and the services of labour.

(14) See the neutral technical progress models of R. Harrod, The 'neutrality' of improvements, Economic Journal, June 1961; J. Hicks, The theory of wages, London, MacMillan, 1963; and R. Solow, Technical change and the aggregate production function, Review of Economics and Statistics, August 1957.

(15) For a review of the use of CES production functions see M. Brown (ed.), The theory and empirical analysis of production, New York, Columbia University Press, 1967.

(16) See, among others, R.M. Solow, Investment and technical progress, in Mathematical methods in the social sciences, J.K. Arrow et al., Stanford University Press, 1969; L. Johansen, Substitution vs. fixed production coefficients in the theory of economic growth: a synthesis,Econometrica, Vol. 27, No. 2, April 1959; B.F. Massel, Investment, innovation and growth, Econometrica, Vol. 40, April 1962; Solow et al., Neo-classical growth with fixed factor proportion, Review of Economic Studies, April 1966.

(17) See N. Kaldor, A model of economic growth, The Economic Journal, Vol. LXVII, December 1957; N. Kaldor and J. Mirrlees, A new model of economic growth, Review of Economic Studies, Vol. XXIX, June 1962; K.J. Arrow, The economic implications of learning by doing, Review of Economic Studies, Vol. XXIX, June 1962.

(18) F. Gonzales Vigil, La modelización neo-clásica del progreso técnico y de la acumulación de capital, Cuadernos, Lima, Centro de Investigaciones, Universidad del Pacífico, Serie Ensayos No. 4, January 1974, p. 25.

(19) W.D. Nordhaus, Invention, growth and welfare, Cambridge, Mass., MIT Press, 1969.

(20) E. Heckscher, The effect of foreign trade on the distribution of income, Economisk Tidskrift, XXI, 1919.

(21) E. Ohlin, Interregional and international trade, Cambridge, Harvard University Press, 1933.

(22) P. Samuelson, International trade and the equalization of factor prices, Economic Journal, June 1948; International factor price equalization once again, Economic Journal, June 1949.

(23) H. Johnson, Technology and economic interdependence, London, St. Martin's Press, 1975, p. 34.

(24) M. Posner, International trade and technical change, Oxford Economic Papers, Vol. 13, 1961, pp. 323-341.

(25) Hufbauer, Synthetic materials and the theory of international trade, London, Duckworth, 1965.

(26) H. Johnson, op. cit., p. 36.

(27) R. Vernon, International investment and international trade in the product cycle,Quarterly Journal of Economics, May 1966,

(47) Ibid., p. 20.

(48) A recent authoritative report prepared by R. Eckaus and the U.S. National Academy of Sciences, Panel on appropriate technologies for developing countries, surveys the field in detail. See Appropriate technologies for developing countries, Washington, D.C.,National Academy of Sciences, 1977.

(49) W.W. Rostow, The stages of economic growth, Cambridge University Press, 1960.

(50) W.W. Rostow, Politics and the stages of growth, Cambridge University Press, 1971, p. 54.

(51) Ibid., p. 57.

(52) W.W. Rostow, The take-off into self-sustained growth, Economic Journal, March 1956. Reprinted in The economics of underdevelopment, eds. Agarwala and Singh, London, Oxford University Press, 1958, p. 154.

(53) Ministry of Science and Technology, Republic of Korea, The long-term plan for scientific and technological development (summary), Seoul, January 1970.

(54) See, for example, W.F. Wertheim, Evolution and revolution, Middlesex, Penguin, 1974.

(55) S. Kuznets, Underdeveloped countries and the pre-industrial phase in the advanced countries, in The economics of underdevelopment, eds. Agarwala and Singh, London, Oxford University Press, 1958.

(56) S. Kuznets, Modern economic growth: findings and reflections, Nobel Memorial Lecture, December 11, 1971. Reprinted in his book, Population, capital and growth, New York, W.W. Norton, 1973, p. 179.

(57) Ibid., p. 180.

(58) G. Myrdal has dealt with these issues extensively in Chapter 14 (differences in initial conditions) of his Asian drama, New York, Pantheon, 1968.

(59) For overviews of the ECLA school of thought see R. Prebisch, Estudio económico de América Latina 1949, Santiago de Chile, ECLA, 1951 (reprinted in 1973); R. Prebisch, El desarrollo económico de América Latina y algunos de sus principales problemas, Boletin Económico para America Latina, Vol. VII, No. 1, February 1961; C. Furtado, Desarrollo y estancamiento en America Latina: un enfoque estructuralists, Desarrollo Económico, Buenos Aires, Vol. 6, No. 22-23, July/December 1966; A. Pinto, Diagnosticos, estructuras y esquemas de desarrollo en America Latina, Boletin de la Escuela Latinoamericana de Sociología, Chile, 3rd year, No. 5, June 1970; and America Latina: el pensamiento de la CEPAL, Santiago de Chile, Ed. Universitaria, 1969.

(60) Prebisch, in his Economic study of Latin America 1949, Santiago de Chile, ECLA, 1951, pointed out additional differences between the early phases of industrialization of developed countries and of the presently developing countries: "when the present large industrial centres were in a situation comparable to that of the peripheral countries now, and their income per capita was relatively small, the technology of production also required

a relatively small investment per man....savings are not large or small on their own right, but rather in comparison with the density of capital resulting from technical progress....The later modern technology arrives to a peripheral country, the more acute will be the contrast between the exiguous amount of its income and the considerable magnitude of the capital required to increase this income rapidly." Cited by Pinto in La CEPAL y el problema del progreso técnico, Trimestre Económico, Vol. 43, April-June 1976, pp. 267-284.

(61) C. Furtado, Obstacles to development in Latin America, New York, Anchor, 1970, p. xvi. The same point has been made by O. Sunkel and P. Paz, El subdesarrollo Latinoamericano y la teoria del desarrollo, Mexico, Siglo XXI, Editores, 1969.

(62) See R. Prebisch, Problemas teóricos y prácticos del crecimiento económico, Santiago de Chile, CCLA, 1952 (reprinted in 1953), p. 21 and following; for a more recent analysis of the technological implications of import substitution industrialization see A. Sanchez Crespo, Esbozo del desarrollo industrial de América Latina y de sus principales implicaciones sobre el sistema científico y tecnológico, Washington, D.C., Dept. of Scientific Affairs, OAS, 1972; D. Felix, Technological dualism in late industrializers: on theory, history and policy, The Journal of Economic History, Vol. 34, March 1974, pp. 194-238; F. Sagasti y M. Guerrero, El desarrollo científico y tecnológico de América Latina, Buenos Aires, BID/INTAL, 1974; and M. Halty, Producción, transferencia y adaptación de tecnología industrial, Washington, D.C., Dept. of Scientific Affairs, 1972.

(63) For a good summary of the controversy on import substitution see A. Hirschman, The political economy of import-substituting industrialization in Latin America, Quarterly Journal of Economics, Vol. 82, February 1968, pp. 1-32.

(64) See R. Prebisch, Transformación y desarrollo, Washington, D.C., Interamerican Development Bank, 1969.

(65) Pinto, op. cit., pp. 274-275; see also his Concentración del progreso técnico y de sus frutos en el desarrollo Latinoamericano, El Trimestre Económico, Vol. 32, No. 125, 1965. In this regard ECLA's Economic study of Latin America for 1973 pointed out that "there are large differences in productivity and modernity between and within the sectors of economic activity, but at the same time there are complex linkages of interchange, domination, and dependence within a socioeconomic national 'structure,' in contraposition to supposed 'dualistic' situations in which two economic structures coexist in the national territory - one 'modern' and the other 'traditional' or 'primitive' - with scant interchange between them and little mutual influence." For a development of the concept see A. di Filippo and S. Jadue, La heterogeneidad estructural: concepto y dimensiones, Trimestre Económico, Vol. 43, No. 169, January-March 1976.

(66) O. Sunkel, Transnational capitalism and national disintegration in Latin America, Social and Economic Studies, Vol. 22, No. 1, 1973; External economic relations and the process of development: suggestions for an alternative analytical framework, Discussion paper No. 51, Institute of Development Studies, Sussex, 1974.

(67) For the role of MNCs see also F. Fanjzylber and T. Morán, Las empresas transnacionales en la economía mexicana, Mexico, Pondo de Cultura Económica, 1976, and G. O'Donnell and D. Linck, Dependencia y Autonomía, Buenos Aires, Amorrortu, 1974.

(68) C. Furtado, El mito del desarrollo económico y el futuro del tercer mundo, Buenos Aires, Periferia, 1974.

(69) Furtado has also advanced a structuralist view of the present crisis of capitalism in his El capitalismo posnacional: interpretación estructuralista de la crisis actual del capitalismo, Trimestre Económico, Vol. 42, No. 168, October-December 1975.

(70) C. Furtado, Economic development of Latin America, Cambridge University Press, 1970, p. 258. For a more recent statement of his views see his El conocimiento económico de America Latina, Comercio Exterior, May 1976, pp. 524-529.

(71) The "dependency" school of thought is a radical offshoot of the structuralist one.

(72) Prebisch's influence on UNCTAD, and through it on economic policies of less developed countries, is widely acknowledged. The work of S. Amin,particularly his L'accumulation a l'echelle mondiale, Paris, Anthropos, 1971, was influenced heavily by the work of ECLA and by the dependency theories of Gunder Frank. See also G. Arrighi and J.S. Saul, Ideology and development: essays on the political economy of Africa, Nairobi, East Africa Publishing House, 1970.

(73) For a detailed study of these concepts and issues see O. Cardettini (ed.), Technological dependence and self-reliance in underdeveloped countries, Lima, STPI project, mimeo, 1976. The volume gathers the points of view of several authors who wrote on these issues at the request of the Coordinating Committee of the STPI project.

(74) Among the representative works of the dependency school, the following may be consulted: F.H. Cardoso and E. Faletto, Dependencia y desarrollo en América Latina, Mexico, Siglo XXI, 1969; F.H. Cardoso, Notas sobre el estado actual de los estudios sobre dependencia, in Desarrollo Latinoamericano, ed. J. Serra, Mexico, Fondo de Cultura Económica, 1974; A. Gunder Frank, El desarrollo del subdesarrollo, in Economía política del subdesarrollo en América Latina, Buenos Aires, Signos, 1970; A. Gunder Frank, Dependence is dead, long live dependence and the class struggle, Latin American Perspectives, Vol. 1, No. 1, Spring 1974; A. Gunder Frank, Capitalism and underdevelopment in Latin America, New York, Monthly Review Press, 1967; T. Dos Santos, El nuevo caracter de la dependencia, Santiago de Chile, CESO, Cuaderno NI, 1968; T. Dos Santos, La nueva dependencia, Lima, Instituto de Estudios Peruanos, 1971; P. Paz, Dependencia financiera y desnacionalización de la industria interna, Santiago de Chile, ILPES, mimeo, June 1969; A. Quijano, Redefinición de la dependencia y marginalización en América Latina, Santiago de Chile, CESO, mimeo, 1970; F. Weffort, Notas sobre la 'teoría de la dependencia': teoría de clase o ideología nacional?, in Teoría, methodología y política del desarrollo en América Latina, FLACSO-UNESCO, Santiago de Chile, 1970. For a good English summary of the theory of dependence see R. Chilcote and J. Edelstein, Latin America: the struggle with dependency and beyond, New York, John Wiley & Sons, 1974. For a very good reappraisal by perhaps the best exponent of the theory see F. Cardoso, Dependency revisited, Hackett Memorial Lecture, Institute of Latin American Studies, University of Texas at Austin, 1973. Dependency theory has also stimulated attempts at understanding underdevelopment in Africa; see, for example, W. Rodney, How Europe underdeveloped Africa, East Africa Publishing House, 1974, and J. Rweyemamu, Underdevelopment and industrialization in Tanzania, Nairobi, Oxford University Press, 1973.

(75) A. Aguilar, cited by O. Cardettini, op. cit.

(76) F. Sagasti, Technological self-reliance and cooperation among Third World countries, World Development, Vol. 4, 1976, pp. 939-949.

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(78) G. O'Donnell and D. Linck, Dependencia y autonomía, Buenos Aires, Amorrortu, 1974.

(79) C. Thomas, Dependence and transformation, New York, Monthly Review Press, 1974.

(80) For a review see D. Abad Arango, Technología y dependencia, El Trimestre Económico, Vol. 40, No. 158, April-June 1973.

(81) G. O'Donnell and D. Linck, op. cit.

(82) C. Thomas, op. cit. p. 195.

(83) Ibid., pp. 195-225.

(84) On the concepts of self-reliance and its various interpretations see O. Cardettini, op. cit.; A. Parthasarathi, The role of self-reliance in alternative development strategies, Report of the 24th Pugwash Symposium, Dar-es-Salaam, June 1975; W. Chagula et al., Pugwash on Self-Reliance, New Delhi, Ankur Publishing House, 1977; and What now?, Report of the Dag Hammarskjold Foundation, Uppsala, June 1975.

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(86) F. Sagasti, Technological self-reliance and cooperation among Third World countries, World Development, Vol. 4, 1976, pp. 939-946.

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(88) J. Bain, op. cit.

(89) See Sylos Labini, op. cit., chap. 2, sec. 8.

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(95) Merhav, op. cit.

(96) Sylos Labini, op. cit.

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(98) F. Fajnzylber, Oligopolio, empresas transnacionales y estilos de desarrollo, El Trimestre Econômico, Vol. 43, No. 171, July-September 1976, pp. 625-656.

(99) Ibid., p. 645.

(100) N. Rosenberg, Marx as a student of technology, Monthly Review, Vol. 28, No. 3, July-August 1976. He also discusses this subject in Chapter 7 of his book Perspectives on technology, Cambridge, Cambridge University Press, 1976.

(101) K. Marx, Capital, Vol. 1, Middlesex, Penguin, 1976, p. 284.

(102) Marx pointed out that "The most essential condition for the production of machines by machines was a prime move capable of exerting any amount of force, while retaining perfect control," ibid., p. 506.

(103) N. Rosenberg, op. cit. pp. 64-65.

(104) K. Marx, op. cit., p. 506.

(105) Ibid., p. 617.

(106) Ibid., pp. 617-618.

(107) Ibid., pp. 775-777.

(108) Marx called the relation between the value of the means of production (constant capital) and the value of labour-power (variable capital) the "organic composition of capital." The relation between the "mass of the means of production employed...and the mass of labour necessary for their employment" was called the "technical composition of capital" (ibid., p. 762). Marx saw that, in the long run, technical progress under capitalism would increase the organic and technical composition of capital.

(109) See K. Marx, Capital, Vol. 1,part 4, and Vol. 3, sec. 3.

(110) The promotion of labour-intensive techniques has been denounced by some as a way of maintaining backwardness under capitalist structures. For example, see S. Barrio, Technological dependence?, paper prepared for the STPI project, Lima, April 1975.

(111) The concepts of concentration and centralization are discussed by

Marx in Vol. 1, chap. 25, sec. 2 of Capital, op. cit., pp. 772-781.

(112) See the writings of V.I. Lenin on the question of markets (between 1893 and 1899, Complete writings, Vols. 1-4); and on Imperialism (between 1915 and 1961, Complete writings, Vol. 22).

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(117) A.P. Usher, A history of mechanical inventions, Harvard University Press, 1954, cited in Kennedy and Thirlwall, op. cit.

(118) L. Nasbeth and G.F. Ray (eds.), The diffusion of new industrial processes, Cambridge University Press, 1974.

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(120) N. Rosenberg, Perspectives on technology, Cambridge, Cambridge University Press, 1976, p. 77.

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(123) C. Freeman, op. cit., chap. 8, pp. 255-282.

(124) H. Townsed, Big business and big science, Science and Public Policy, Vol. 1, No. 10, p. 292.

(125) Pavitt, op. cit., pp. 34-35.

(126) Kennedy and Thirlwall, op. cit., p. 61. See also Kamien and Schwartz, op. cit.,pp. 14-19.

(127) The report by the Center for Policy Alternatives at the Massachusetts Institute of Technology, National support for science and technology: an evaluation of foreign experiences, 1976, examines the nature and impact of these government measures in several Western industrialized countries.

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(130) J.R. Hicks, The theory of wages, N.Y., MacMillan Co., 1932, pp. 124-125; W. Salter, Productivity and technical change, Cambridge University Press, 1960, pp. 43-44.

(131) Salter, op. cit., pp. 43-44.

(132) C. Kennedy, Induced bias in innovation and the theory of distribution, Economic Journal, Vol. 74, No. 295; Salter, op. cit., p. 15. For a thorough criticism of this approach see Rosenberg, op. cit., pp. 61-68.

(133) See, for example, S. Hollander, The sources of increased efficiency: a study of DuPont rayon plants, MIT University Press, 1965; R. Shishko, An empirical study of technical change through product improvement, PhD Dissertation, Yale University, New Haven, 1972; J.L. Enos, A measure of the rate of technological progress in the petroleum refining industry, Journal of Industrial Economics, Vol. 6, June 1958; and J. Katz, Importación de tecnología, aprendizaje local e industrialización dependiente,Fondo de Cultura Economica, Mexico, 1975.

(134) See, for example, J.S. Chipman, Induced technical change and patterns of international trade, in The technology factor in international trade, ed. R. Vernon, New York, Columbia University Press, 1971, p. 98.

(135) J. Katz, Transferencia de tecnología, aprendizaje local e industrializacion dependiente crecimiento económico, Mexico, Fondo de Cultura Economica, 1975.

(136) See, for example, A. Rahman, Science, technology and economic development, Delhi, National Publishing House, 1974, particularly Chapter 6 dealing with the drug industry; and B. Bihari, Economic growth and technological change in India, Bombay, Vikas Publishing House, 1974.

(137) See, among others, R. Sautu y C. Wainerman, El empresario y la innovación, Buenos Aires, Instituto Torcuato di Tella, 1971, for a general study of Argentinian entrepreneurs, and Chapter 7 of Rahman, op. cit., for a study of Indian entrepreneurs in the iron and steel industry.

(138) See, for example, G. Boon, Technology markets in some specific fields, paper prepared for the International Development Research Centre, Canada, September 1974; and Economic technological behaviour in development, El Colegio de Mexico, mimeo, July 1973. For a

review of the literature see D. Crane, Technological innovation in developing countries: a review of the literature, Research Policy, Vol. 6, 1977, pp. 374-395.

(139) The study was conducted by the MIT Center for Policy Alternatives and the Fundaçao Carlos Alberto Vanzolini in Sao Paulo. The basic features of this model are summarized in W.J. Abernathy and J. Utterback, A dynamic model of process and product innovation by firms, Center for Policy Alternatives, MIT, May 1975.

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(145) A. Parthasarati (raportteur), The role of technology in alternative development strategies, final report of the 24th Pugwash Symposium, Dar-es-Salaam, June 1975.

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Appendix 1
INSTITUTES AND COUNTRIES PARTICIPATING IN THE STPI PROJECT

Argentina	Secretaria Ejecutiva del Consejo Latinoamericano de Ciencias Sociales (CLACSO) Country Coordinator: Eduardo Amadeo
Brazil	Financiadora de Estudos e Projetos (FINEP) Country Coordinator: Fabio Erber (until September 1974) and José Tavares
Colombia	Fondo Colombiano de Investigaciones Cientificas y Proyectos Especiales "Francisco José de Caldas" (COLCIENCIAS) Country Coordinator: Fernando Chaparro
Egypt	Academy of Scientific Research and Technology Country Coordinator: Adel Sabet (until July 1975) and Ahmed Gamal Abdel Samie
India	National Committee on Science and Technology Country Coordinator: Anil Malhotra (until June 1975) and S.K. Subramanian (until March 1976)
South Korea	The Korea Advanced Institute of Science (KAIS) Country Coordinator: KunMo Chung
Mexico	El Colegio de Mexico Country Coordinator: Alejandro Nadal
Peru	Instituto Nacional de Planificacion (INP) Country Coordinator: Enrique Estremadoyro (until February 1975) and Fernando Otero Technical Directors: Fernando Gonzales Vigil (until February 1975) and Roberto Wangeman
Venezuela	Consejo Nacional de Investigaciones Cientificas y Tecnologicas (CONICIT) Country Coordinator: Dulce de Uzcategui (until July 1974) and Ignacio Avalos
Yugoslavia (Macedonia)	Faculty of Economics, University of Skopje Country Coordinator: Nikola Kljusev

Appendix 2
SURVEY OF THE COUNTRY TEAM'S WORK

The organization, composition, and orientation of each of the country teams reflected the own interests and those of the institutions that hosted them, always within the framework of the STPI project concerns. A brief review of the approach and the work of each team may help to place the STPI project and the comparative reports in perspective. To complete the survey, a description of the field coordinator's office work is given.

ARGENTINA: The initial location for the Argentine team was the Department of Economics of the Catholic University. However, after some months, the university decided to withdraw its application and the country coordinator moved to the Argentine branch of the executive secretariat of the Latin American Social Science Council (CLACSO). The team was headed by Eduardo Amadeo, an economist, and two other members were appointed to work full time on the project. An advisory committee of several researchers and policymakers active in science and technology policy was formed. To carry out the research, the team relied on consultants who wrote reports on specific subjects that were integrated into a final report.

A significant change took place when the country coordinator was named president of the Instituto Nacional de Tecnologia Industrial (INTI), the national industrial technology institute, which is the largest and most important industrial research organization in Argentina. Mr Amadeo never relinquished his formal role as coordinator; after 6 months, he left his new post and resumed his position as country coordinator. Because most of the work was well under way, his absence did not substantially alter the team's pace, although the preparation of the Argentine synthesis report was postponed. Part of the team's work was reoriented to be most useful to the coordinator in his new position.

The Argentines focused on two branches of industry - machine tools and petrochemicals - but studied many broader issues. For instance, the reports include a document on the technological content of the 3-year development plan (1974-77), a study of the Argentine industrial structure, a description and brief analysis of technology policy instruments in Argentina, a study of the system for regulating technology imports, and several short reports on international technical assistance as an instrument of technology policy.

The structure of the Argentine scientific and technological system was studied in detail, as were the conditions under which it could be made more responsive to industry's needs. The Argentines covered the public sector, examining the possible role of the public sector as promoter of scientific and technological development. Detailed studies were carried out at two enterprises: one in charge of generating electricity in Buenos Aires (SEGBA) and the other in charge of generating and distributing gas for household and industrial consumption. Other contributions of the Argentine team were a study of the emergence and development of engineering and consulting firms in the chemical process industries, a detailed analysis of two research centres within the national industrial technology institute (INTI), and two short papers on capital accumulation and on the crisis of capitalism.

The Argentine team followed the methods guidelines; however, they produced a series of thematic reports on issues of actual and potential interest to policymakers in the country, coinciding with the themes selected for study in STPI.

BRAZIL: The Brazilian team was hosted at the research group of the Financiadora de Estudos e Projetos (FINEP), the state agency in charge of financing studies for investment projects and also the executive arm of the national fund for scientific and technological development. The first coordinator was the director of the research group,

Fabio Erber. When he took a leave of absence from FINEP in September 1974, he was replaced by José Tavares, the new head of the research group. The group at FINEP had been carrying out research on science and technology policy for some time, and the STPI assignment was one of its tasks for 1973-76. Practically all of the work was done by members of the FINEP research group, although two or three reports were contracted to professionals outside FINEP.

From the beginning, the Brazilians decided to concentrate on the role of state enterprises in technology policy. They chose branches of industry that were dominated by state enterprises (oil and petrochemicals, steel, and electricity), conducting detailed interviews, analyzing existing data, and testing hypotheses systematically to cover issues such as the selection of equipment and processes, the purchase of engineering services, the performance of research and development, and the planning activities at these state enterprises.

In addition to the new material generated by the Brazilian team during STPI, several reports based on past research carried out by FINEP were made available to the STPI network. These included background reports on the organization and structure of the Brazilian science and technology system, a study on the machine tool industry, a report on the demand for services of 12 research institutes, and a background report on industrial policies in Brazil during the last 2 decades.

In parallel with the work for STPI, the FINEP team was also engaged in a research project on the diffusion of technical innovations in three industrial branches (pulp and paper, cement, and textiles) and they agreed to put their results at the disposal of the STPI network as an additional contribution.

The Brazilian team used the guidelines only as a general reference, given that most of their work went along different lines from those originally envisaged for the project. Nevertheless, the richness and variety of their material effectively upgraded the comparative reports.

COLOMBIA: No Colombian participant was present at the initial organizing meeting, and the Colombian application to join the STPI network was received later and formally accepted at the Rio meeting of the coordinating committee. The team was hosted by the Colombian Council for Science and Technology, COLCIENCIAS, and was headed by a sociologist, Fernando Chaparro. In spite of joining the STPI network late, the Colombian team caught up with the pace of work and finished all its work by the deadline.

COLCIENCIAS organized a special team with five members who devoted practically all their time to research in STPI. Several other consultants were also asked to prepare reports on issues of specific interest such as selected policy instruments. For example, a study was commissioned on the impact of tariff mechanisms; a report was prepared on the influence of price controls; and a preliminary analysis of the possible use of the state's purchasing power as an instrument of technology policy was also prepared. The branches chosen for study were all linked to agriculture: fertilizers and pesticides, agricultural machinery, and food processing, taking into consideration the interests of Colombian policymakers as perceived by the team. In these branch studies, the methods guidelines were closely followed.

Other reports prepared by the Colombian team include a study of science and technology planning, an analysis of implicit industrial technology policies, a conceptual framework for the study of consulting and engineering organizations, a series of reports on industrial branches based on discussions with panels of experts, a study of science and technology policies in the agricultural sector (to complement the analysis done for industry), and two essays on the process of industrialization in Colombia and its technological implications.

Five groups of policy instruments were studied in detail, and their impact on each branch was examined through interviews at various enterprises. All of the findings were integrated into the final report of the Colombian team.

EGYPT: Although an Egyptian representative participated in the initial deliberations leading to the STPI project, it was not possible to organize the team to carry out

research and prepare inputs for the international comparison. There were several administrative difficulties and staffing problems that prevented the organization of a working team. The host institution was the Academy of Scientific Research and Technology and the first coordinator was Adel Sabet, who was replaced by Gamal A. Samie in July 1975. The Egyptian team presented papers that were personal contributions based on past experience rather than the result of research carried out by a team; and research was not begun at the academy until the second half of 1976.

INDIA: The host organization in India was the National Committee on Science and Technology, and the first coordinator was Anil Malhotra, who was replaced in June 1975 by S.K. Subramanian. Mr Subramanian resigned in March 1976, and no one replaced him. No funds were requested to set up a country team in India, and the Indians provided background material that had already been collected as background for a new science and technology plan.

Three background documents were distributed along with the final S & T plan to all the teams in STPI. In addition, a report on foreign collaboration, a note on science and technology planning in India, a survey of engineering consultancy services, a report on the development of the electronics industry, and two papers on small-scale industries and technology transfer were distributed by the Indian coordinator. No empirical research was done following the methods guidelines, and the Indian contribution to the comparative reports reflects this.

SOUTH KOREA: The South Korean team was one of the first to be organized and was established at the Korean Advanced Institute of Science, KAIS, as part of the activities of its science, technology, and society program. KunMo Chung was named country coordinator and the team consisted of five other members. All but one of them had other academic duties and could allocate only a portion of their time to STPI research. Then, Graham Jones was hired to advise in the preparation of the report for phase 1.

The South Korean team advanced rapidly and completed its work in time for the Sussex workshop, following the methods guidelines and introducing modifications only where necessary. Two reports were produced corresponding to the requirements for phases 1 and 2 of the project.

The branches chosen for study were electronics, petrochemicals, and powder metallurgy, and a report was prepared for each one. In addition, the team prepared documents on engineering services and industrialization in South Korea, on the Korean Institute of Science and Technology, on transfer of technology in the electronics industry, on the interface between the science and technology plan and the economic development plan, and on state enterprises in technical development.

Although most of the work was done by the team located at KAIS, consultants were asked to deal with specifics. The team predominantly represented engineering and physical sciences, but an economist who was a senior government official, helped to relate the results to South Korean policymakers and to balance the other team members' biases.

MEXICO: The Mexican team was among the first to start working in STPI and was located at El Colegio de Mexico, an academic and social research and graduate training organization. Alejandro Nadal was country coordinator and there were four other members of the team who worked full time on STPI. The Mexican team initially followed the guidelines rather closely and was one of the first in suggesting modifications and changes as a result of contrasting concepts with preliminary research findings. In particular, the team found it difficult to interpret the results of interviews in enterprises using the schema proposed to study technological behaviour. The branches chosen for detailed study were capital goods, food processing, and petrochemicals.

A background report on the structure and evolution of the Mexican scientific and technological system was prepared, together with a description of the industrialization process and of agricultural development. Documents on particular subjects included a report on engineering firms, a study of the technology policy of PEMEX (the state oil monopoly), and progress reports dealing with hypotheses on the impact of policy instruments on technical behaviour at the enterprise level, a description of policy ins-instruments in Mexico, etc.

Most of the findings of the Mexican team were integrated into the main final report, part of which was delivered at the coordinating committee in New Delhi (January 1976) and the rest at the Sussex workshop (June 1976). The work of the Mexican team covered practically all the research topics considered in STPI, and its contribution to the comparative report reflects this. The Mexican report was published in Spanish in 1977 and was awarded second prize in a contest for the best works in economics.

For various reasons, the Mexican team chose to limit its direct interaction with policymakers and followed its own research program. Results were made available to policymakers in the form of draft reports, and through the participation of the coordinator in one of the committees established to prepare the Mexican plan for science and technology.

PERU: The Peruvian team was established within the research group of the National Planning Institute. A series of administrative difficulties affected the progress of the team, including a change of technical director, when Fernando Gonzales Vigil was replaced by Roberto Wangeman in February 1975. Approximately two-thirds of the research was completed in time for the Sussex workshop.

From the beginning, the team decided to adopt a sectorial approach to the research. Efforts were focused on the study of industrial branches connected with the extraction and processing of minerals and with the provision of machinery for the mining industry. The steel industry was also studied, with emphasis on the state enterprise in charge of the largest steelworks. This meant that the guidelines were used primarily in sectorial studies and in the analysis of policy instruments.

Background reports on the situation of the scientific and technological system and on the evolution of Peruvian industry were prepared following the general framework put forward in the guidelines. In addition to these and the sectorial reports, the team prepared other documents, dealing with issues such as explicit and implicit science and technology policies, consulting and engineering capabilities, the possible use of state enterprises as instruments of technology policy, and the government administrative machinery for science and technology policy.

The Peruvian team was located within an official government organization, but its direct impact on policymaking is difficult to assess because it took the form of daily contact with government officials. On the basis of the sectorial reports on mining, a committee has been set up to review the findings of the STPI team.

VENEZUELA: The Venezuelan team was hosted by the national council of science and technology (CONICIT) and was among the first to start working. The team was initially dominated by sociologists, although economists increased their participation at later stages. The first coordinator, Dulce de Uzcategui, was replaced by Luis Matos, who was soon followed by Ignacio Avalos. Three other members worked full time, and the team was biased toward sociology and economics.

They progressed through two stages punctuated by a change in government. In the first stage, most of the background reports corresponding to phases 1 and 2 of the STPI methods were prepared, covering the science and technology, the political, the educational, and the economic systems. These reports were made obsolete by the change in government. In the second stage, the team tried to adjust to the new situation, repeating some of the earlier studies and continuing the research. However, the organization of a national congress on science and technology, which mobilized all the staff working at CONICIT, affected the team's progress.

The branches chosen for study were capital goods, electronics, and petrochemicals. In addition, reports were written on specific issues such as the government organizational structure for science and technology policy, instruments for industrial science and technology policy, economic and financial policy instruments and their impact on technology, the purchase of capital goods in two industrial branches, and the relations between the financial system and technology policy. The Venezuelan team concluded its research shortly after the Sussex workshop.

The fact that the Venezuelan team was located in a government agency that took

a very active role in science and technology policy after the change in government created both opportunities and problems. As a result of the new tasks undertaken by CONICIT, the pace and continuity of the STPI work was frequently altered. On the other hand, there was more possibility for actively contributing to policymaking. The Venezuelan contribution to the comparative reports reflects this situation.

YUGOSLAVIA (MACEDONIA): The Macedonian team was organized at the faculty of economics of the University of Skopje. A senior faculty member, Nikola Kljusev, was appointed coordinator. The team was composed of a very large number of faculty members and researchers who devoted part of their time to STPI. The tasks were subdivided and individual reports requested from various members of the team, although at a later stage two team members were asked to work full time on STPI.

The Macedonian team did not follow the guidelines, except in the preparation of a background report for phase 1. Individual reports were submitted on issues of interest to the STPI network, covering topics such as the problems of research and development in industrial enterprises, aspects of science and technology policy in Yugoslavia, the metallurgical industry in Macedonia, and the growth of engineering firms in Yugoslavia.

The Macedonian team's specificity is reflected in their relatively limited contribution to the comparative reports. At any rate, given the high degree of participation of professionals at all levels in policymaking in the Yugoslav self-managed economy, it is rather difficult to assess their contribution toward policymaking in conventional terms.

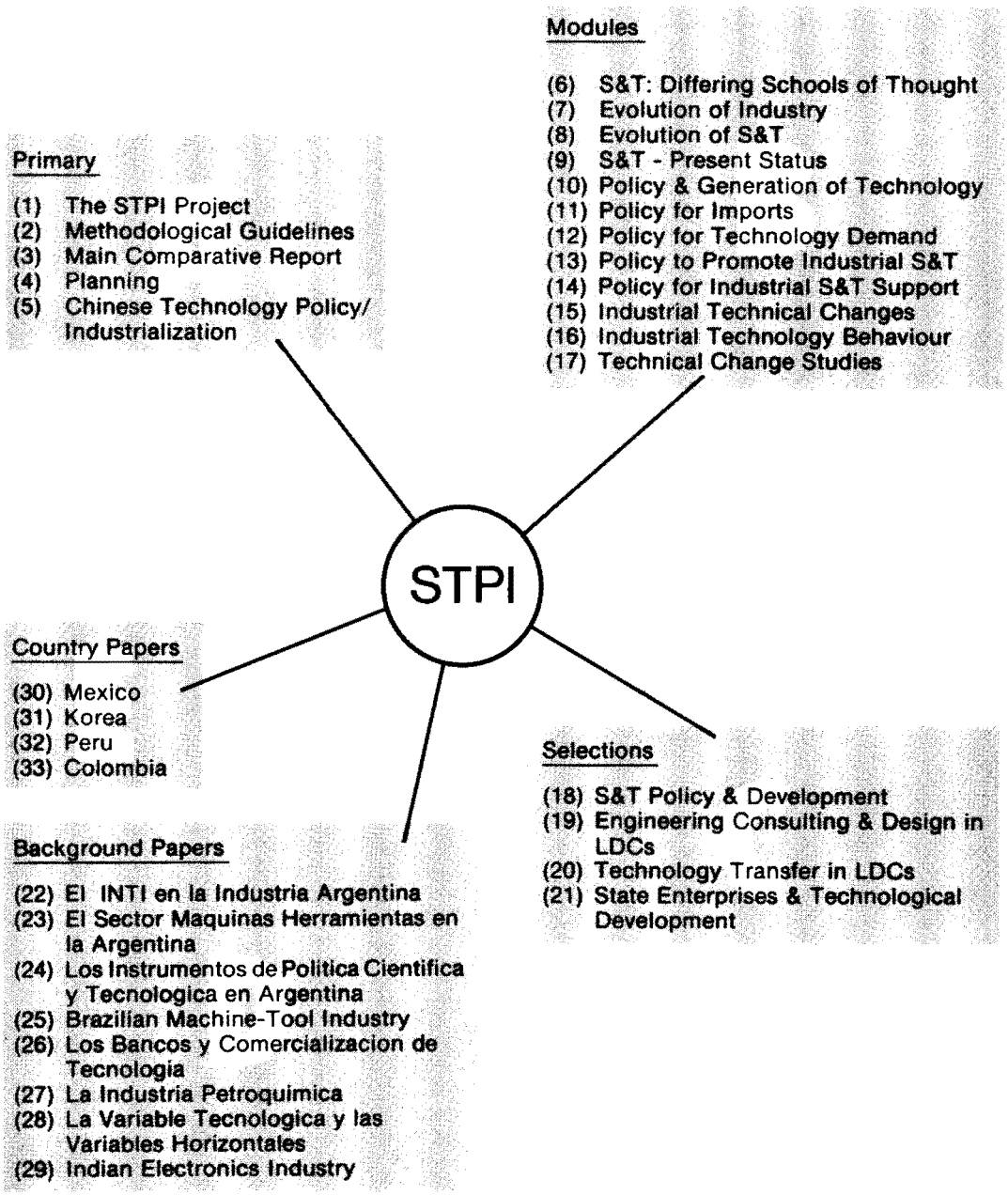
THE FIELD COORDINATOR'S OFFICE: In August 1973, at the first meeting of the coordinating committee, Francisco Sagasti was appointed field coordinator of the project and his office was established shortly thereafter and began operating in a limited way. Staffing was completed in April 1974 with the addition of two members.

The field coordinator's office was independent from the teams and was not engaged directly in empirical research. It offered organizational and technical support and contracted consultants to prepare reports on topics defined by the coordinating committee.

The field coordinator, first, drew up methods guidelines for phases 1 and 2 of the project. Background reports on technology policy in China, on technological dependence/self-reliance, on science and technology planning, on technology policies in Japan, and on technology transfer were also prepared, either by staff members of the field coordinator's office or by consultants. The guidelines for phases 3 and 4 of the project were prepared jointly by the field coordinator and a consultant. The office also organized the Sussex workshop and drafted the comparative reports. The field coordinator was also active in the board of the Peruvian Industrial Technology Institute (ITINTEC).

With the exception of the teams that were engaged in science and technology policy research as part of the activities of their institutions (the Brazilian and South Korean teams, for example), the teams were dismantled after the STPI project was completed. The field coordinator's office was closed in December 1976, and the comparative reports were prepared during 1977-1978, although some teams had not finished their work by April 1978. Even though most teams had concluded their STPI activities by the end of 1977, this does not mean that the team members left the field of S & T policy research and that their effort in STPI was not followed up. What was dismantled, as planned from the beginning, was the formal structure of the STPI project. The network of personal contacts remains in operation and most of the former team members are active in the field of science and technology policy, carrying the experience accumulated in STPI to their new positions.

Key to STPI Publications



A GUIDE TO THE SCIENCE AND TECHNOLOGY POLICY INSTRUMENTS (STPI) PUBLICATIONS

A. Primary Publications

(1) The Science and Technology Policy Instruments (STPI) Project (IDRC-050e) (out of print)

(2) Science and Technology Policy Implementation in Less-Developed Countries: Methodological Guidelines for the STPI Project (IDRC-067e) (out of print)

(3) Science and Technology for Development: Main Comparative Report of the STPI Project (IDRC-109e). (Also available in French (IDRC-109f) and Spanish (IDRC-109s).)

(4) Science and Technology for Development: Planning in STPI Countries (IDRC-133e)

(5) Science and Technology for Development: Technology Policy and Industrialization in the People's Republic of China (IDRC-130e)

B. Modules

These constitute the third part of (3) above and provide supporting material for the findings described and the assertions made in (3).

(6) STPI Module 1: A Review of Schools of Thought on Science, Technology, Development, and Technical Change (IDRC-TS18e)

(7) STPI Module 2: The Evolution of Industry in STPI Countries (IDRC-TS19e)

(8) STPI Module 3: The Evolution of Science and Technology in STPI Countries (IDRC-TS20e)

(9) STPI Module 4: The Present Situation of Science and Technology in the STPI Countries (IDRC-TS22e)

(10) STPI Module 5: Policy Instruments to Build up an Infrastructure for the Generation of Technology (IDRC-TS26e)

(11) STPI Module 6: Policy Instruments for the Regulation of Technology Imports (In press)

(12) STPI Module 7: Policy Instruments to Define the Pattern of Demand for Technology (IDRC-TS27e)

(13) STPI Module 8: Policy Instruments to Promote the Performance of S and T Activities in Industrial Enterprises (In press)

(14) STPI Module 9: Policy Instruments for the Support of Industrial Science and Technology Activities (In press)

(15) STPI Module 10: Technical Changes in Industrial Branches (In press)

(16) STPI Module 11: Technology Behaviour of Industrial Enterprises (In press)

(17) STPI Module 12: Case Studies on Technical Change (In press)

C. Selections

These are a selection of the numerous reports prepared for the STPI Project chosen as a representative sample of the various topics covered by the STPI Project in the course of the main research effort on policy design and implementation.

Science and Technology for Development: A Selection of Background Papers for the Main Comparative Report.

(18) Part A: Science and Technology Policy and Development (IDRC-MR21)

(19) Part B: Consulting and Design Engineering Capabilities in Developing Countries (IDRC-MR22)

(20) Part C: Technology Transfer in Developing Countries (IDRC-MR23)

(21) Part D: State Enterprises and Technological Development (IDRC-MR24)

D. Background Papers

(22) El INTI y el Desarrollo Tecnologico en la Industria Argentina (In press)

(23) El Sector Maquinas Herramientas en la Argentina (In press)

(24) Los Instrumentos de Politica Cientifica y Tecnologica en Argentina (In press)

(25) The Brazilian Machine-Tool Industry: Patterns of Technological Transfer and the Role of the Government (In press)

(26) Rol de los Bancos en la Comercializacion de Tecnologia (In press)

(27) Comportamiento Tecnologico de las Empresas Mixtas en la Industria Petroquimica (In press)

(28) Interrelacion Entre la Variable Tecnologica y las Variables Horizontales: Comercio Exterior, Financiamiento e Inversion (In press)

(29) A Planned Approach for the Growth of the Electronics Industry — A Case Study for India (In press)

E. Country Reports

(30) Instruments of Science and Technology Policy in Mexico (In press)

(31) Technology and Industrial Development in Korea (In press)

(32) Los Instrumentos de Politica Cientifica y Tecnologica en el Peru: Sintesis Final (In press)

(33) STPI Country Report for Colombia (In press)